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Metals and Alloys

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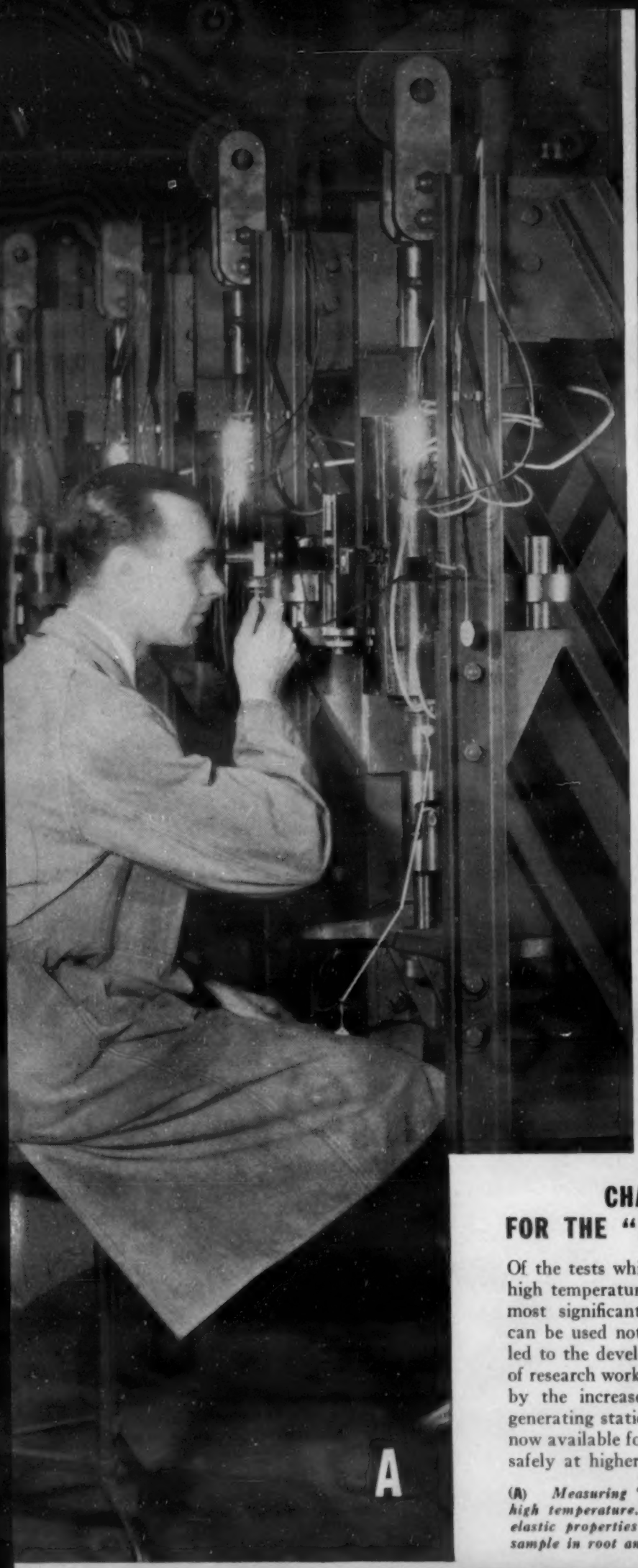

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CHARTING A SAFE COURSE FOR THE "HIGH TEMPERATURE" DESIGNER

Of the tests which attempt to duplicate service conditions of high temperature operation, the long-time "creep" test is the most significant. The information obtained from this test can be used not only for avoiding failures in design but has led to the development of new and stronger steels. The value of research work such as this is demonstrated in a striking way by the increased fuel economy being reported by central generating stations which, because of the stronger steel alloys now available for high temperature service, are able to operate safely at higher temperatures and pressures.

(A) *Measuring "creep" in tests for slow yielding under stress at high temperature.* (B) *Taking exact measurements of strength and elastic properties of steel at high temperature.* (C) *Testing welded sample in root and face bending jig.*

A

B

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An Announcement

Beginning with this issue—July—a few changes are announced:

The year's issues are divided into two volumes, January to June and July to December. Volume XII begins with this issue.

Material which until now had been divided between two departments — "New Equipment and Materials" and "News"—will be integrated into one section with the title—"Metallurgical Engineering News."

A new department is initiated entitled: "Metallurgical Engineering Shop Notes"—in which interesting and pertinent items of general interest will be published every month or so.—The Editors.

Brighten the Corner

There's a gospel hymn that goes "Brighten the corner where you are." The message is generally applicable. Firms which can help in military preparedness or which require strategic materials are, of course, active in aiming for the greatest possible production and for savings in, or substitutes for, the strategic materials they require. However, it is probable that individual metallurgists have experience with, or ideas on, the use of substitutes that have not been put into use because, under ordinary conditions, the scheme is not economical. They may not be in a position to develop the ideas or perfect the practice because they are now fully occupied in other lines.

It is particularly useful to develop methods of use of substitute materials that, without much regard to cost, fit in with existing equipment and with the methods in which the shop men are trained, so that in a pinch upon strategic materials, production can be kept up while the necessary equipment for more radical changes in methods is being installed. We shall probably not lack the strategic materials, but we should be prepared for remote eventualities of this nature.

Instead of waiting for some central authority to work out all the ways of saving strategic materials and to give instructions to that end, there should be a spontaneous passing around of ideas and experiences that would normally never be discussed, much less published, because of their inapplicability to normal conditions.

Metallurgists have long given thought to these problems. If the pertinent thoughts are expressed, somebody can make use of them, to the benefit of all of us, if emergency arises. If no emergency arises, it will nevertheless have been useful to have known of the various ways by which it could have been met, had it arisen.

Economics ordinarily defeat a lot of such schemes that would be perfectly fine technically. Now is a time when schemes that are technically sound, but have been regretfully tucked away because of the cold facts of comparative costs, may be well worth dusting off, especially if they will work with the equipment we have.

We shall be glad to publish articles, notes, or letters, dealing with substitution of strategic materials or methods of saving them.—H. W. G.

Manganese

The American steel industry is evidently becoming more aware of the necessity of meeting the need for manganese—a subject stressed here and by others since the European war started.

In the first four months of this year imports of manganese ore of metallurgical grade have averaged over 89,000 net tons per month—a volume far in excess of recent years.

Production of ferromanganese by American blast furnaces to June 1 has averaged over 43,000 net tons per month—a total in excess of the present consumptive needs and one not equalled in many months or years. This would indicate accumulation of stocks.

No substitute for manganese has been offered by research, and steel can hardly be made without manganese. The only possible substitute that has received attention is zirconium, and there is some question as to a supply of this metal. With the spread of the war and the possibility of our supply of ore being menaced, the trends here noted as to increased supply are encouraging.—E. F. C.

(Continued on page 52)

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Titanium and Some Properties of Cr-Mo Steel for Airplane Tubing

by GEORGE F. COMSTOCK

Metallurgist, Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

IN VIEW OF THE DIFFICULTIES that have been encountered occasionally in welding chromium-molybdenum steel tubing for airplane construction, some experiments were undertaken to determine whether small additions of titanium to the SAE X4130 steel would improve its ductility and weldability without impairing any other useful properties of the steel. Since titanium additions to other steels of somewhat similar composition have been found sometimes to reduce the strength, the effects of higher manganese, and of copper additions, were also investigated with the thought that such changes would counteract any reduction in strength while still permitting titanium to improve the ductility and weldability.

The Heats Investigated

Eight heats of steel having the analyses shown in Table I were made for this investigation in a basic-lined 17-lb. induction furnace, and the ingots were rolled to 7/8-in. diameter rounds. No aluminum was added to any of the steels, except for the aluminum present in the titanium alloy used. This was the regular grade of TAM low-carbon 40 per cent ferrotitanium, containing 40.86 Ti, 7.70 Al, 3.21 Si and 0.06 per cent C. No titanium was added to heat No. 1. All the heats received the same chromium and molybdenum additions, and were made with the same scrap charge. Their chromium contents were between 0.97 and 1.04 per cent; molybdenum was about 0.20 per cent, phosphorus about 0.019 per cent, sulphur about 0.026 per cent, and copper (except where extra copper was added) about 0.06 per cent in all the heats. The samples for analysis were taken about 1/2-in. above the bottom ends of the ingots.

The amounts of titanium and aluminum added in the ferrotitanium and the recovery of titanium are given in Table II. These data are computed on the assumption that each melt contained 0.006 per cent Ti without any ferrotitanium addition.

The greater part of each of the 7/8-in. round bars was cut into short lengths which were normalized 1 1/2 hrs. at 1650 or 1750 deg. F., and machined afterward to standard tensile and Izod-impact test specimens. Two tensile test-bars were normalized at each temperature, and both of those normalized at 1650 deg. F. were tested without further treatment. The results reported for that treatment are, therefore, averages from two tests each. After machining the tensile test-bars that were normalized at 1750 deg. F., one of each pair was stress-relieved 16 hrs. at 400 deg. F., and these results are reported separately. None of the impact test specimens were stress-relieved, and the impact values that are reported are averages from four tests. The results of all these tests are assembled in Table III. The yield strengths were taken as the stress producing a deformation, under load, amounting to 0.5 per cent, or 0.01 in. which was measured with a Berry strain gage on the 2-in. gage length.

Table I. Chemical Analyses of the Small Ingots Used.

Heat No.	Carbon	Manganese	Silicon	Titanium	Copper
1	0.34	0.55	0.24	0.006	...
2	0.33	0.60	0.28	0.039	...
3	0.34	0.58	0.24	0.068	...
4	0.34	0.56	0.18	0.104	...
5	0.30	0.48	0.18	0.150	...
6	0.34	0.85	0.19	0.093	...
7	0.33	0.48	0.23	0.090	0.31
8	0.34	0.54	0.25	0.098	0.78

Table II. Titanium and Aluminum Added in the Fe-Ti and the Recovery of Titanium.

Heat No.	Total Metallic Charge, Grams	Ferrotitanium Added, Grams: Total	Ferrotitanium Added, Grams: Al Content	Ferrotitanium Added, Grams: Ti Content	Per Cent Added: Al	Per Cent Added: Ti	Ti Recovered in Steel: Grams	Ti Recovered in Steel: Per Cent
1	8076	0	0	0	0	0	0	0
2	8084	8	0.62	3.27	0.008	0.040	2.66	81.4
3	8090	19	1.46	7.76	0.018	0.096	5.02	64.6
4	8096	30	2.31	12.26	0.029	0.152	7.93	64.7
5	8112	41	3.16	16.77	0.039	0.206	11.68	69.7
6	8123	30	2.31	12.26	0.028	0.151	7.06	57.6
7	8121	30	2.31	12.26	0.028	0.151	6.82	55.6
8	8161	30	2.31	12.26	0.028	0.150	7.51	61.3

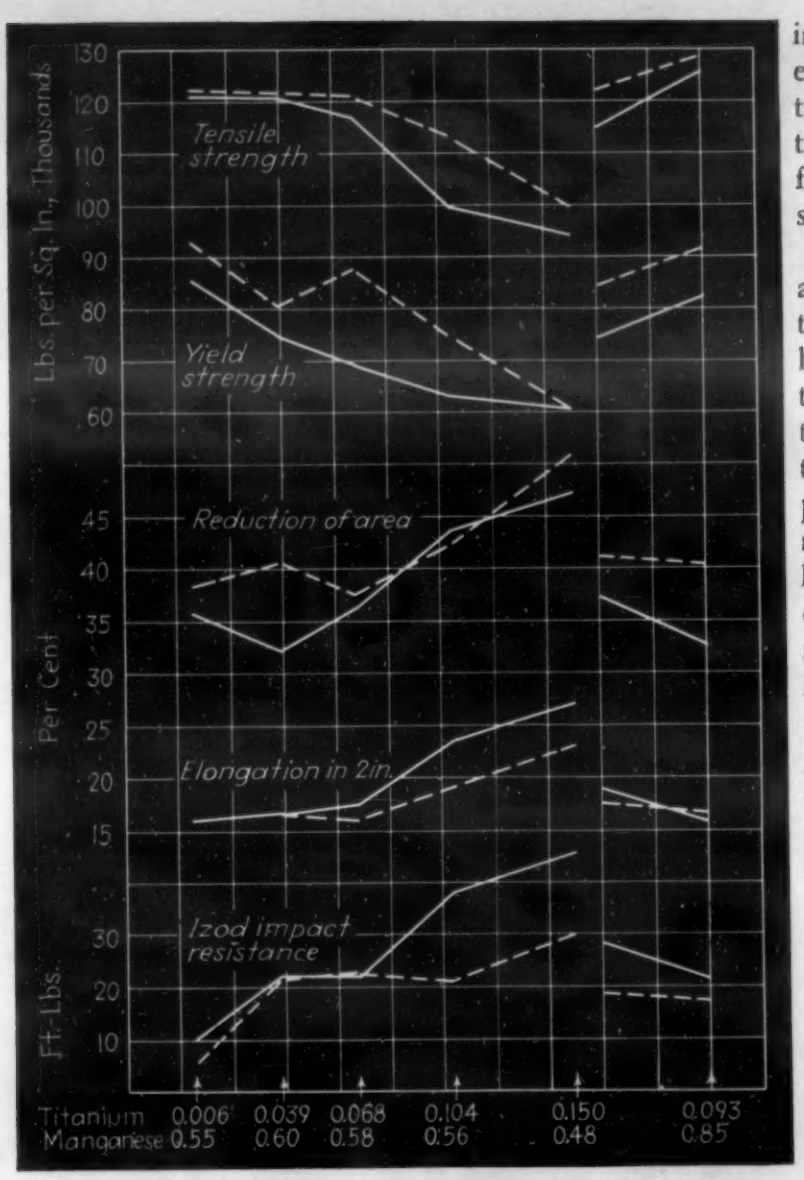


Fig. 1. Effect of Ti and Mn on properties of 1 per cent Cr, 0.20 per cent Mo steels.

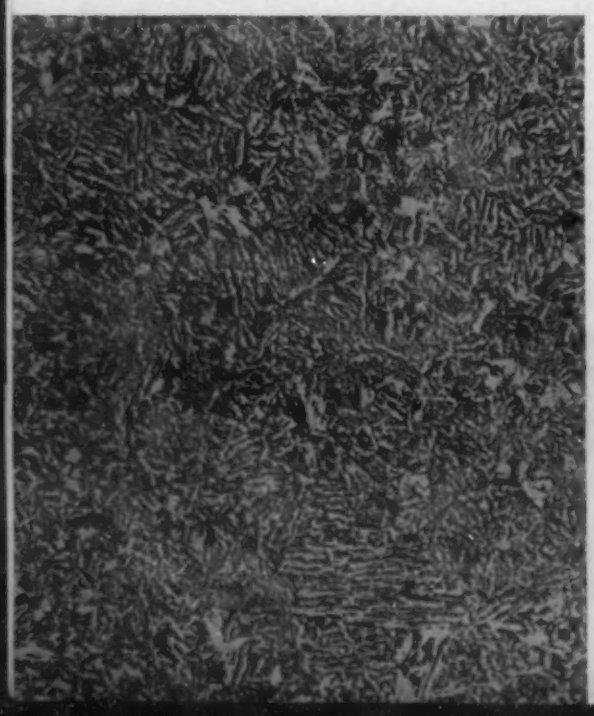
Some of the data in Table III are plotted in the form of graphs in Fig. 1, which shows how the properties changed with increasing titanium contents. At the right-hand side some additional points are plotted to indicate the effect of the increased manganese in heat No. 6. The lines drawn from the latter points are directed to the points representing the lower-manganese steel of approximately equal titanium content, and indicate merely whether the increased manganese tended to raise or lower the value of the property designated. The results from the tempered or stress-relieved tensile test specimens are not plotted in Fig. 1.

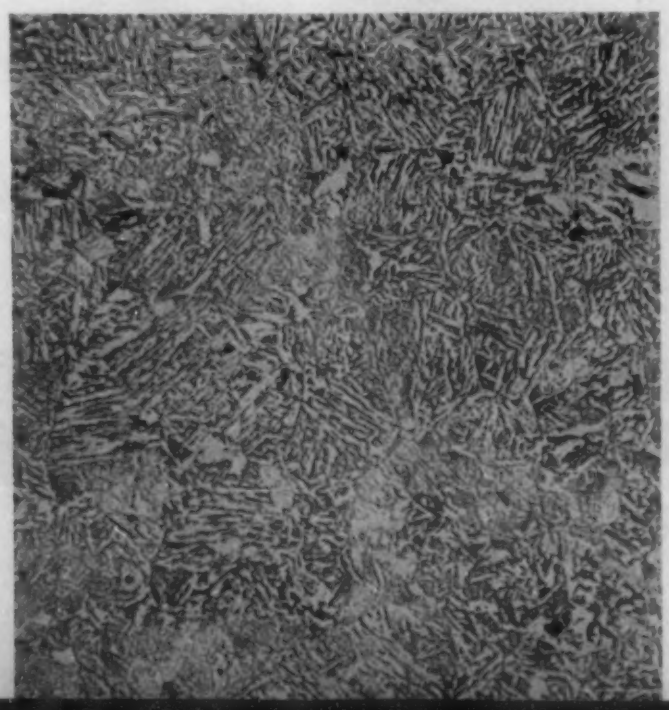
Table III and the graphs show that all the titanium additions, even as little as 0.039 per cent, decreased the yield strength and raised the impact resistance, but it required more than 0.068 per cent Ti to affect the tensile strength and ductility appreciably. With the manganese increased from 0.56 to 0.85 per cent, the yield strength of the steel with 0.093 to 0.104 per cent Ti was brought back to the value for the non-titanium steel, with the tensile strength even higher, ductility about the same, and impact value equal to that of the low-titanium and lower-manganese steels, or two or three times as high as in the non-titanium steel. The copper additions were not as advantageous as increasing the manganese, since when the yield strength of the titanium steel was raised sufficiently by copper, the ductility and impact values, as shown in Table III, were too much impaired.

Normalizing at 1750 deg. F. instead of 1650 deg. F. improved the yield and tensile strengths of all these steels, and the reduction of area too in most instances. The elongation and impact resistance were generally not improved, however, by normalizing at the higher temperature. The low-temperature tempering or aging, after normalizing at 1750 deg. F., raised the yield strength of the copper steels decidedly, but seemed to have a slight softening effect on the others, decreasing some of the strengths a little and improving the ductility. This is indicated only in Table III, and not in Fig. 1.

Cross sections of the tensile test stubs were cut at the shoulders and polished for microscopic examination. The steels were all fairly clean and those with the most titanium showed only a few small titanium cyanonitride crystals. The specimens were etched with nitric acid to show their microstructures,

Fig. 2. Typical angular structure of the untreated steel, No. 1, normalized at 1650 deg. F., etched with nitric acid. 200X. Fig. 3. Same as Fig. 2, except normalized at 1750 deg. F. Fig. 4. Typical fine-grained structure of the titanium steel, No. 2 with 0.039 per cent Ti, normalized at 1750 deg. F. showing ferrite and pearlite or sorbite. Etched and magnified like Fig. 2.





which were quite fine in every instance. Some photomicrographs are presented as Figs. 2 to 7 inclusive to illustrate them. The non-titanium steel showed after both heat-treatments a much more angular structure than the titanium steels in which the ferrite and pearlite patches occurred in the form of rounded grains rather than in needle-like or "Widmanstätten" patterns. In the higher manganese and copper steels much of the pearlite did not seem to be perfectly formed, but was either extremely fine or of a sorbitic nature. These steels did not show any reversion, however, to the angular structure typical of the non-titanium steel.

It may be concluded from these results that even as little as 0.039 per cent Ti added to this 1 per cent Cr 0.20 per cent Mo steel produced a decided improvement in the microstructure and impact resistance after normalizing. The yield strength, however, was slightly reduced. To overcome this reduction in yield strength, raising the manganese content was effective, and with 0.85 per cent Mn and 0.093 per cent Ti the improvement conferred by the titanium on the microstructure and impact resistance was maintained without appreciable impairment of the yield strength value. It might be pointed out here that this manganese content is no higher than is permitted in the SAE 4135 specification, which covers steel No. 6 in every respect. In view of these beneficial effects of the presence of about 0.1 per cent Ti in this steel, and the other satisfactory properties found with the manganese content raised to 0.85 per cent, it was decided that welding tests should be made.

Weldability

The method chosen for determining the weldability was adopted from the paper by Harter, Hodge and Schoessow on "The Value of Electric Arc Welding in Design and Its Limitations" (Am. I. & S. Inst., May 25, 1939). Owing to the small size of the bars available, it was not possible, however, to use

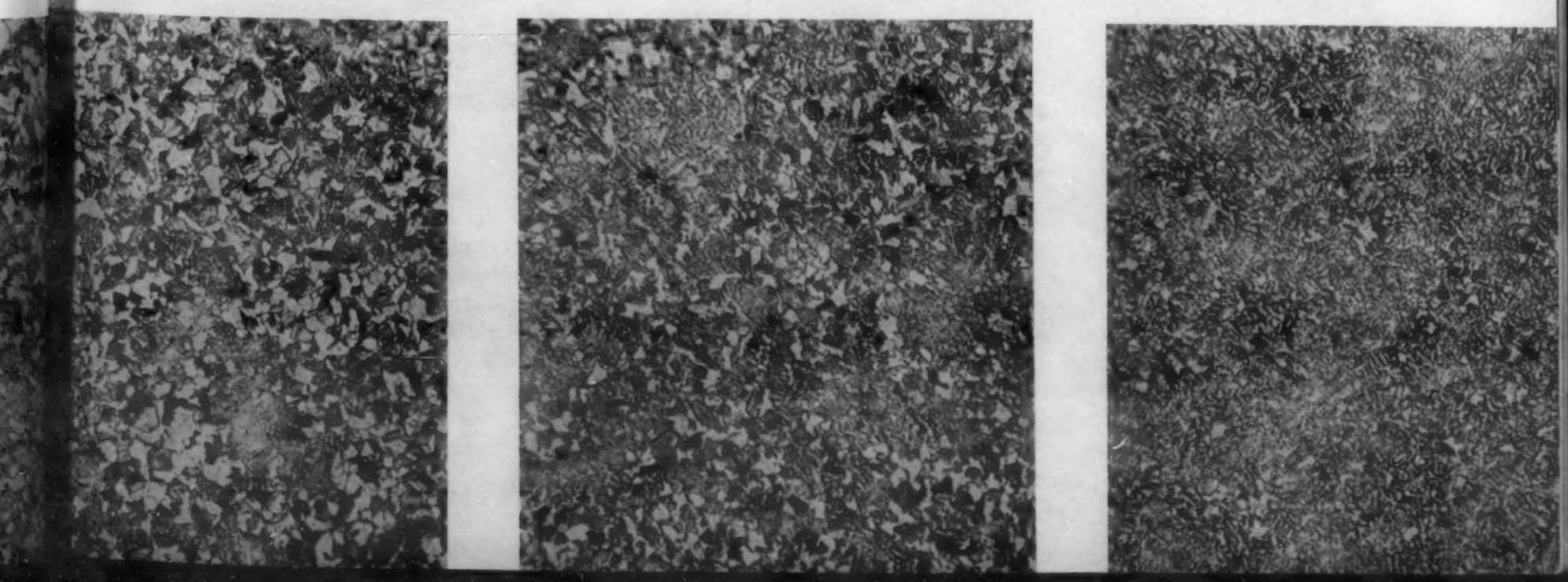
Table III. Tensile and Impact Test Results.

Heat No.	Titanium Content	Other Variations in Analysis	Heat Treatment, deg. F.		Lbs. per Sq. In.		Per Cent		
			Normalize	Temper.	Yield Strength	Tensile Strength	Elongation	Red. Area	Izod Impact Value
1.	Untreated	...	1650	...	85600	121150	16.0	35.8	10.0
			1750	...	93000	122000	15.5	38.4	5.2
			1750	400	90400	122600	16.5	43.0	...
2.	0.039	...	1650	...	74600	120900	16.5	32.1	22.0
			1750	...	80500	121600	16.5	40.5	21.2
			1750	400	75100	117100	18.5	43.5	...
3.	0.068	...	1650	...	69000	116600	17.3	36.2	21.7
			1750	...	87200	120800	16.0	37.5	22.0
			1750	400	85900	121300	19.5	47.2	...
4.	0.104	...	1650	...	63200	99800	23.5	43.6	38.0
			1750	...	74500	113000	19.0	42.2	21.0
			1750	400	72600	111800	19.5	45.0	...
5.	0.150	...*	1650	...	60400	94000	27.0	47.3	45.7
			1750	...	60500	99200	23.0	51.0	30.0
			1750	400	63200	94900	26.0	53.8	...
6.	0.093	0.85 Mn	1650	...	82800	125500	15.8	32.8	21.2
			1750	...	91700	129000	16.5	40.3	17.2
			1750	400	93000	127300	17.5	44.0	...
7.	0.090	0.31 Cu	1650	...	75700	124300	17.0	33.8	17.0
			1750	...	86200	130200	16.5	35.2	17.7
			1750	400	92000	129900	19.0	45.5	...
8.	0.098	0.78 Cu	1650	...	88700	144800	14.0	23.8	11.5
			1750	...	93500	147100	16.0	33.0	10.5
			1750	400	103000	147300	14.5	36.0	...

* This heat had 0.30% C instead of the 0.33 to 0.34% C of the other heats.

½-in. plates, but the round bars were flattened by forging to flats about 2 by ¼ in., which were normalized 1½ hrs. at 1650 deg. F. The scale was then removed from one side of each piece by sandblasting, and a weld bead was deposited lengthwise along the middle of that side. The welding was all done by the same operator at a temperature of about 55 deg. F., using 5/32-in. No. 5 coated Fleetweld electrodes, with 200 amp., 75 v., and the electrode positive. The beads deposited averaged about 7/16-in. wide, and a single electrode was consumed in making each one 12 in. long, with one exception. The time of welding was controlled as carefully as possible, and was measured with a stop-watch. The

Fig. 5. Same as Fig. 4, except showing steel No. 4, with 0.104 per cent Ti. Fig. 6. Typical structure of steel No. 6, with 0.093 per cent Ti and 0.85 per cent Mn, normalized at 1750 deg. F., showing less ferrite and more sorbite. Etched with nitric acid. 200X. Fig. 7. Same as Fig. 6, except showing steel No. 8, with 0.098 per cent Ti and 0.78 per cent Cu.



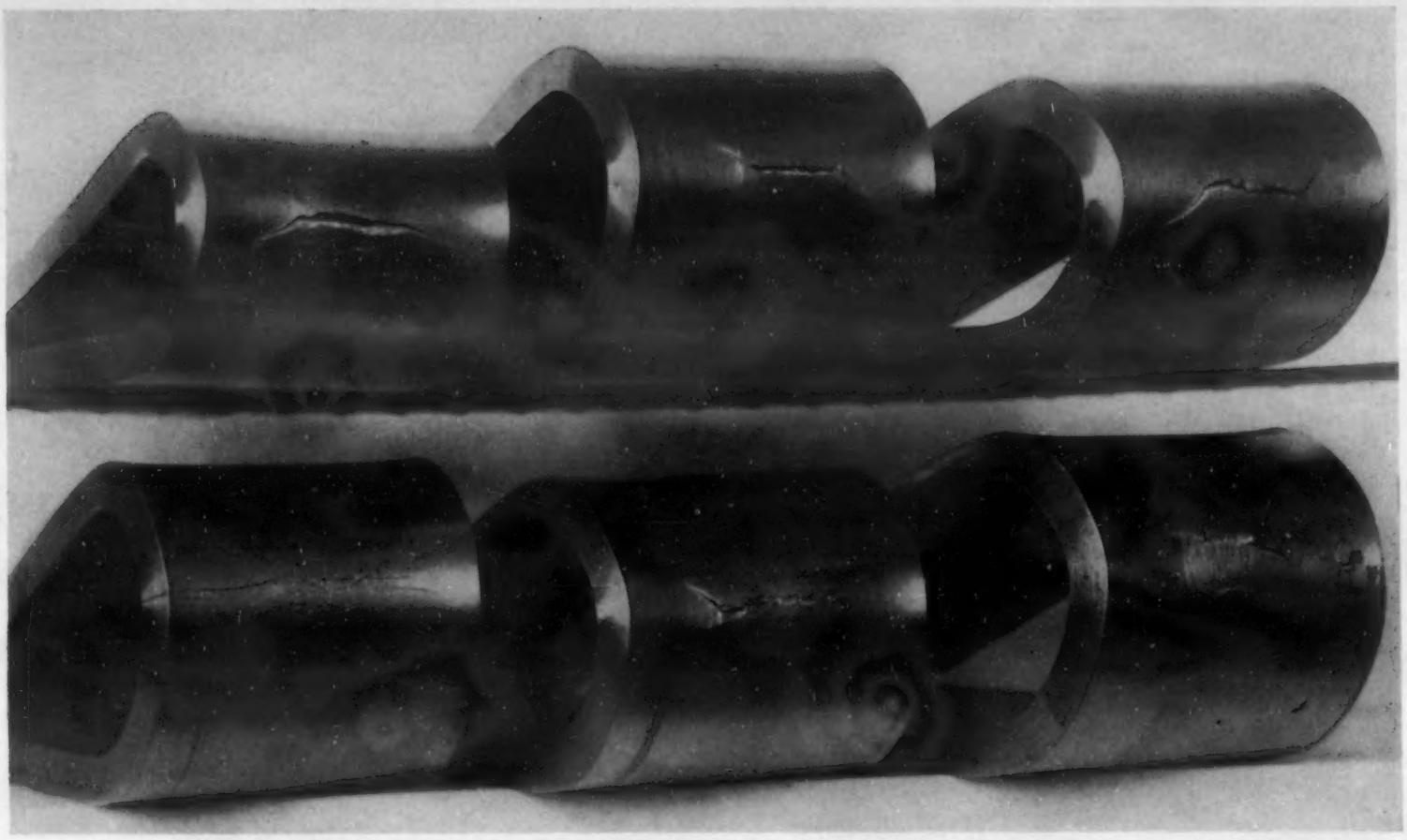


Fig. 8. Normalized samples welded lengthwise, machined flat and bent with the weld on the outside until cracks began to extend beyond the weld beads. Magnified about 1.5 diameters. Upper row, left, is No. 5 (0.15 per cent Ti); middle is No. 6 (0.093 per cent Ti, 0.85 per cent Mn); right is No. 7 (0.09 per cent Ti, 0.31 per cent Cu). Lower row, left is No. 1 (untreated); middle is No. 2 (0.039 per cent Ti); right is No. 4 (0.104 per cent Ti). Note that No. 1 is the only one cracked through the edge, and with a smaller rupture of the weld bead.

time did not vary much from the desired period of 72 sec., except in one instance. This exception was the No. 2 sample, which was welded too slowly, so that the electrode was consumed when the bead was only about 8 in. long, and a second electrode had to be used to finish it. The samples were laid on the floor, each one separately, to cool after welding.

Bend test specimens were cut 9½ in. long from the welded samples, measuring from the end where the weld was started. The beads were ground flat on these specimens, and their sides trimmed to give a width of 1½ in. with the bead in the middle. One-inch lengths were marked with a punch along the center, and the specimens were bent slowly in an Olsen cold-bend machine around a pin of 1.5 in. diameter, with the weld on the outside. None of the specimens cracked in this test, which was continued to a bend of 170 deg. The bends were then flattened in a compression machine until cracks occurred outside the welds. The No. 1 specimen was the only one that cracked suddenly across both the weld and the plate at the same time; in all the rest the cracks started in the welds and extended so slowly into the plates that the tests could be stopped just as the plates began to crack, but before the cracks reached the edges of the specimens.

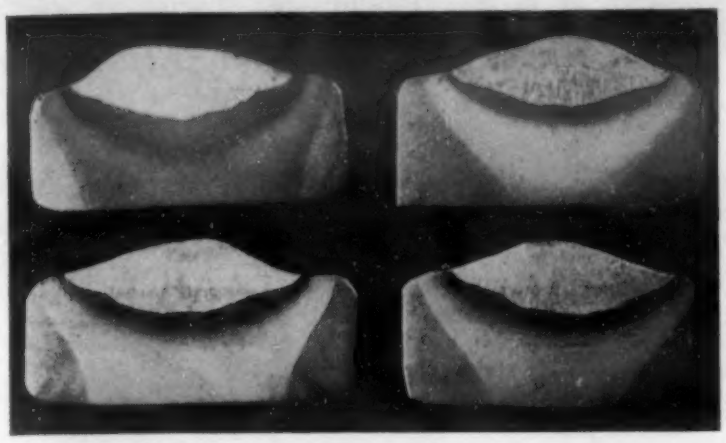
To evaluate these results, the maximum outside width across each bent specimen was measured, a smaller width indicating that the welded steel could be bent further without serious cracking except inside the weld bead. The elongation between the punch marks nearest the crack was also measured with a flexible tape, and here, of course, the larger figures indicate higher ductility. These values together with the welding rates and notes on the manner in which cracking occurred, are reported in Table IV.

All the steels containing titanium show better results in Table IV than the untreated in elongation and type of failure, and only in the high copper steel was much less flattening of the bend permissible without penetration of the cracking from the weld metal through the plate. The slow welding rate of sample No. 2 should be noted, as this apparently had the same effect on the ductility as a higher titanium content would have had. Fig. 8, which is a photograph of the bent specimens, shows the character of the failures.

Hardness Tests

Cross sections of the weld deposits were cut for etching and hardness tests just beyond the bend test pieces. This means that they were about 9¾ in. from the start of the weld except in sample No. 2,

Fig. 9. Polished and etched cross-sections of the weld beads, magnified about 2.5 diameters, showing the coarsened and hardened zones as dark strips below the brighter weld metal. Upper left is No. 1 (untreated); upper right is No. 4 (0.104 per cent Ti); lower left is No. 6 (0.093 per cent Ti, 0.85 per cent Mn) lower right is No. 7 (0.09 per cent Ti, 0.31 per cent Cu).

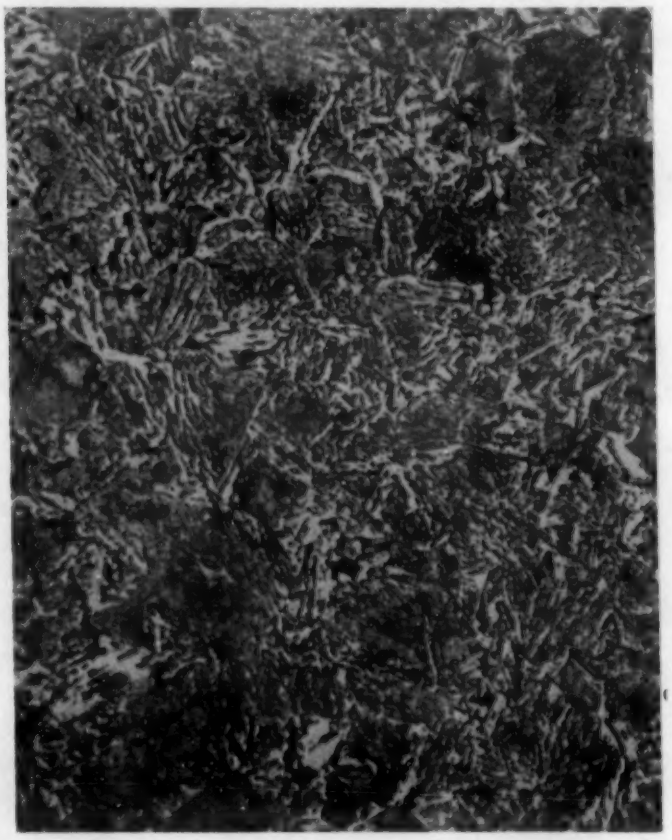


where the cross section was about 1½ in. from the point where the second weld rod was started. The sections were filed smooth and etched to show the extent of the weld metal and of the hardened zone beneath. The hardness tests were made by the Rockwell method using the C scale. Four tests were made in a straight line transversely across the section, starting at about the middle of the weld bead. The results are given in the same order in Table V, the first one of each set of four showing the hardness of the weld deposit, and the others that of the heat-affected zone below it. The last reading of the four was taken nearest the lower surface of the plate.

Eight additional hardness tests were made on each section in a row extending lengthwise through the base of the weld deposit. Four of these tests were made on one side of the crosswise row, and four on the other side. These results are reported in Table V in sets of 8, in consecutive order from one end of the row of tests to the other. The actual lengths of these rows of hardness tests varied from ⅞ to 1 in., and the four middle tests of the row were generally within the hardened zone. The last column in Table V shows the difference between the lowest and highest reading on the base metal of each welded sample, excluding the weld metal, and thus affords a comparison of the various steels on the basis of hardening due to welding under the conditions used in this work.

Although the softening effect of the higher titanium contents is apparent in Table V, the hardening due to welding did not decrease proportionately with increasing titanium. The slower welding rate for sample No. 2 seems to have had more effect than the higher titanium contents of other samples. Heat No. 6, the titanium steel with higher manganese, shows up well, as although naturally harder than the titanium steels with normal manganese, it was not hardened quite so much by the welding operation. The copper steels were harder in general, and hardened more or to a higher degree when welded. The hardness tests would probably have

Fig. 10. Cross-section of the No. 1 (untreated) weld photographed 1.5 mm. below the bottom of the bead deposit, etched with picric acid and magnified 500 diameters, showing a coarse acicular structure.



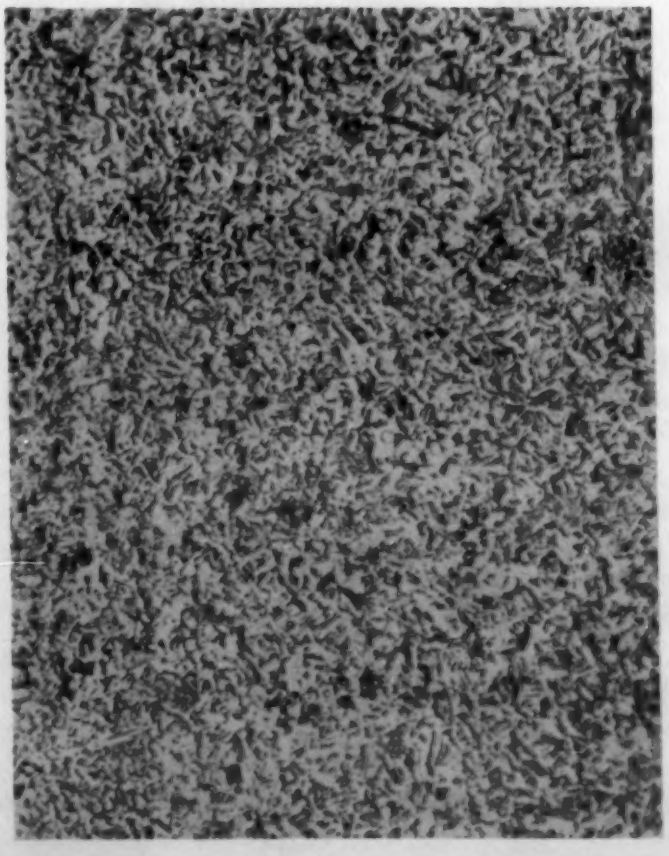


Fig. 11. Same as Fig. 10, except showing the No. 4 weld (0.104 per cent Ti) with a very fine structure 1.5 mm. below the bottom of the bead.

Table IV. Results of Bend Tests on Welded Samples.

Heat No.	Extra Alloy Content	Welding Rate, In. per Min.	Maximum Width of Bend, In.	Elong. in 1 In., Per Cent	How Crack Occurred
1	Untreated	9.8	1.49	21	Suddenly across weld and plate.
2	0.039 Ti	7.1	1.37	27	In weld, and partly into plate.
3	0.068 Ti	10.0	1.51	23	In weld, and partly into plate.
4	0.104 Ti	9.6	1.48	23	In weld, and partly into plate.
5	0.15 Ti*	9.8	1.16	30	In weld, and partly into plate.
6	0.093 Ti, 0.85 Mn	9.0	1.45	24	In weld, and partly into plate.
7	0.09 Ti, 0.31 Cu	10.3	1.27	26	In weld, and partly into plate.
8	0.098 Ti, 0.78 Cu	10.0	1.68	23	In weld, and partly into plate.

* This steel contained 0.30% C instead of the 0.33 to 0.34% C of the others.

Table V. Results of Hardness Tests on Welded Samples.

Heat No.	Extra Alloy Content	Welding Rate, In. per Min.	Rockwell C Hardness Readings	Hardness Range In Plate
1.	Untreated	9.8	14-23-29-29 24-25-29-29-31-30-25-25	8
2.	0.039 Ti	8.4	8-25-27-29 23-24-28-28-28-29-22-24	6
3.	0.068 Ti	10.0	14-25-31-29 26-26-30-34-33-26-26-26	9
4.	0.104 Ti	9.6	15-29-30-27 22-24-22-29-31-23-23-25	9
5.	0.15 Ti (0.30% C)	9.8	16-23-27-25 15-17-17-27-28-17-17-17	13
6.	0.093 Ti, 0.85 Mn	9.0	12-25-30-31 27-26-30-30-33-30-27-28	8
7.	0.09 Ti, 0.31 Cu	10.3	19-25-31-32 28-27-28-33-34-26-27-29	9
8.	0.098 Ti, 0.78 Cu	10.0	22-34-35-29 30-32-38-36-36-34-32-33	9

shown greater variations between the steels if the welded plates had been thicker.

Examination of Structure of Welds

The macrostructures and microstructures of some of the welded samples were examined, using cross-sections cut close to those used for the hardness tests. Fig. 9 is a photograph of four of these, etched to show the weld deposit and the variously affected zones of the base metal. The hardened zone directly beneath the deposit appears dark in this photograph, and beneath it the rest of the plate which was also altered in structure by the heat of welding is differentiated from the unaffected base metal at each side. Fig. 9 shows that, in the untreated sample, No. 1, the hardened zone is deeper than in the others, and that in the titanium steel No. 4 not only is the hardened zone thinner, but the heat-affected zone beneath is also more restricted in area. The other two samples illustrated, containing copper and higher manganese respectively, are intermediate in macrostructure between the first two.

The microstructures did not differ appreciably between the samples except in the extent of the various zones as noted above. The hardened zones were comparatively coarse-grained in all the samples, while further from the weld beads the structure was very fine. Although the weld metal was sharply defined in structure, the coarse and fine zones of the plate beneath merged gradually into each other. In the higher-titanium steels the coarse-grained zone was quite narrow, while in the untreated steel it was much broader. The coarse and fine structures are illustrated in Figs. 10 and 11, which are photomicrographs of the untreated and 0.1 per cent Ti steels, both taken 1.5 millimeters below the bottom of the weld bead. This point was in the coarse zone of the untreated steel, but below the coarse zone of the titanium steel. No distinct martensite was found in any of the specimens, although doubtful traces were suspected at a few points close to the weld in the untreated steel. The hardest sample, No. 8 with 0.78 per cent Cu, showed mostly sorbite, with less ferrite near the weld than in the softer samples, and its structure was not so acicular as that of the untreated steel.

Summary

To summarize the results of the welding tests, the following conclusions may be drawn:

(1) In these forged and normalized SAE X4130 steels, welded lengthwise, machined flat, and bent cold with the weld outside, the presence of titanium improved the bending quality, even when accompanied by higher manganese (as in SAE 4135) or 0.31 per cent Cu. The steels with 0.15 per cent Ti, and with 0.09 per cent Ti and 0.31 per cent Cu, bent the most after welding, without cracking.

(2) The presence of over 0.1 per cent Ti in these samples produced a softer steel, but did not decrease the degree of hardening by welding. With 0.85 per cent Mn and 0.093 per cent Ti the steel was harder than with the normal manganese content, but there was no greater hardening by welding than in the untreated steel. The microstructure showed a narrower hardened and coarsened zone in the titanium steels than in the untreated, especially without copper or increased manganese.

(3) The improved ductility, impact value, and microstructure produced by titanium or Ti + Al, in the normalized test-bars is reflected by a similar improvement in the weld-bend tests. With the manganese increased to about 0.85 per cent and 0.09 to 0.10 per cent Ti in this SAE X4130 steel, the strength in the normalized condition is satisfactory, the hardening by welding is not excessive, and the ductility after welding and resistance to impact are definitely improved as compared with the regular or untreated X4130 steel.

The American Electric and Alloy Steel Industry

by EDWIN F. CONE

THE ANNUAL STATISTICS of the American Iron and Steel Institute are always keenly awaited and carefully studied, particularly if one is interested in the trends in electric and in alloy steel production of the country from year to year.

For several years we have been watching these trends and publishing the results.[1] Last year[2] we adopted a different basis for studying this subject—different from the one used in previous surveys.[1] Instead of, as in the past, adding estimated steel foundry production (not available anywhere for the whole foundry industry) to the data of the Institute, only the Institute's statistics are used. It is believed that, although these data include only the ingot output plus such castings as are made by ingot producers, they definitely show the general trend.

There is therefore here presented an analysis of the trends in electric and alloy steel production of the country based on the statistics of the American Iron and Steel Institute. The data of the Institute for 1939 are, however, presented in net instead of gross tons, necessitating a revision of all previous tables in earlier articles.[1]

Outstanding in the 1939 record is the increase in the electric steel output as well as in stainless steel. Maintenance of the high rate of output of alloy steels in general is also a feature.

Total Electric Steel

The feature of the 1939 record in electric steel is that the percentage of electric steel of the total steel production rose to 1.95 per cent, or the highest ever recorded. At 1,029,067 net tons last year the output was the second largest ever reached—just under the record total of 1,065,603 tons in 1929. Table I presents these and other facts as assembled from the statistics of the Institute.

Table I—Electric Steel Output—Net Tons

Year	Total Electric Steel	Total Steel	Per Cent Electric
1920	566,370	47,188,886	1.20
1929	1,065,603	63,205,490	1.68
1933	471,747	26,020,229	1.81
1934	404,651	29,181,924	1.38
1935	606,471	38,183,705	1.58
1936	865,150	53,499,999	1.62
1937	947,002	56,636,945	1.67
1938	565,627	31,751,990	1.78
1939	1,029,067	52,298,714	1.95

Table II—Production of Alloy Steels Made in Electric Furnaces in the United States—Net Tons

Year	Electric Alloy Steel	Total Alloy Steel	Per Cent of Electric Alloy Steel of Total Alloy
1929	571,234	4,432,072	12.9
1935	462,071	2,374,017	19.4
1936	591,094	3,229,657	18.3
1937	672,616	3,396,541	19.8
1938	373,372	1,653,510	22.5
1939	749,384	3,211,955	23.0

Electric Alloy Steel

The largest amount of alloy steel made in electric furnaces was the record for 1939. Table II presents these data. At 749,384 net tons the electric alloy steel was 23 per cent of the total alloy steel produced. This percentage has also never before been equalled.

These facts regarding electric steel show definitely that the importance of the electric furnace, both arc and induction, in steel making is expanding very rapidly. Part of this expansion is due to the increased demand for stainless steel.

Stainless Steels

A new record in total output of the stainless and heat-resisting steels was made in 1939, according to the American Iron and Steel Institute. Table III reproduces these data which have been collected only since 1934 and which present only the ingot output. Statistics of the American Alloy Castings Association, an organization made up of the stainless steel castings producers, are not made public. The 179,620 net tons of stainless steel ingots produced last year exceed by 14.7 per cent the next highest output of 156,618 tons in 1937.

As in the past the "18 and 8" type is predominant. Last year the 81,144 net tons was 45.3 per cent of the total—a new record. In 1938, the percentage was 44.9 per cent and only 34.5 per cent in 1934.

Table IV shows the percentage of stainless steel of the total alloy steel, compiled from the data of the Institute. While a new total of stainless steel was made last year, there was no gain in the percentage—5.60 per cent for 1939 as compared with 5.81 for 1938. The high proportion reached in

1938 is virtually being maintained.

Since all the stainless steels are made in electric furnaces, it is interesting to note that in 1939 the 179,620 tons of stainless steel was 17.4 per cent of the total electric steel—a new record. In 1938 it was 16.9 per cent and in 1934 only 13.8 per cent—indicating a constant growth.

Total Alloy Steel

Table V presents the data of the Institute for the country's production of ingots and steel for castings, together with the alloy steel output and its relation to the total steel. To and including 1933 the data include both ingot and casting totals, but from 1934 on the statistics (in italics) give only the steel ingots plus such castings as are made by the ingot-producing companies.

Last year no new records were made in total alloy steel, but the pace of the last few years was maintained. The 1939 output at 3,211,955 net tons was the third largest in the last six years and the fourth largest on record. The 1939 total was 6.08 per cent of the total steel output, a substantial increase over 1938 and practically the same as the average percentage for the 4 yrs., 1934 to 1937. In tons of steel to 1 ton of alloy steel (Table V), the record for 1939 at 16.4 tons was equal to the average of the same 4 yrs. This represents a gain over 1938.

Summary

Recapitulating the data presented, the following facts are prominent:

Total electric steel output for 1939 at 1.95 per cent of the total steel was a new record.

A new record in the quantity of alloy steels made in electric furnaces was the history of 1939. It was 23 per cent of the total alloy steel—also a new record.

In the stainless steels a new high total production was recorded—with 18 and 8 leading the procession by an increased proportion.

The percentage of stainless steels of the total alloy steel at 5.60 per cent last year was but little below the 1938 record.

No new records were made in total alloy steel in 1939. The substantial total of 3,211,953 net tons was 6.08 per cent of the total steel output, the highest percentage since 1935.

References

[1] "Trends in Stainless Steel Production," December, 1935, Vol. 6, page 347.
"Trends in American Alloy Steel Production," November, 1935, Vol. 6, page 329.
"Trends in American Alloy Steel Production," June, 1936, Vol. 7, page 162.
"Production Trends of American Alloy Steel and Electric Steel," July, 1937, Vol. 8, page 191.
"Production Trends of American Alloy Steel and Electric Steel," August, 1938, Vol. 9, page 207.
[2] "Trends in Alloy and Electric Steel Output," August, 1939, Vol. 10, page 255.

Table III—Production of Stainless Steel Ingots—Net Tons

Year	"18 and 8"	12 to 14% Cr	16 to 18% Cr	All Others	Totals
1934	22,150	9,970	9,046	14,739	55,905
1935	27,676	14,820	14,377	16,707	73,580
1936	43,800	26,430	23,842	7,810	101,882
1937	66,212	33,938	27,550	28,918	156,618
1938	43,129	13,429	16,454	22,942	95,954
1939	81,144	22,453	34,230	41,793	179,620

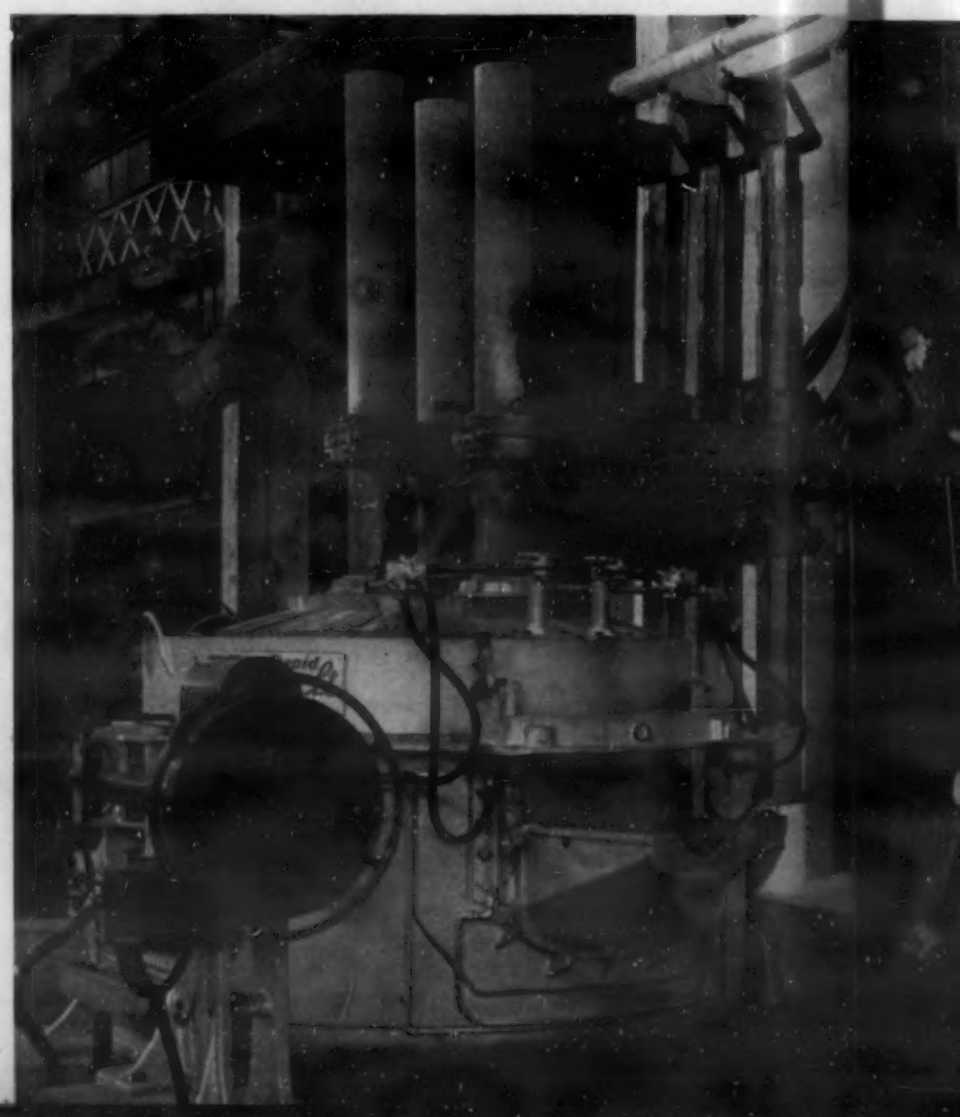
Table IV—Proportion of Stainless Steel of Total Alloy Steel—Net Tons

Year	Total Stainless	Total Alloy Steel	Per Cent Stainless
1934	55,905	1,805,748	3.10
1935	73,580	2,374,017	3.09
1936	101,882	3,229,657	3.16
1937	156,618	3,396,541	4.61
1938	95,954	1,653,510	5.81
1939	179,620	3,211,955	5.60

Table V—Production of Alloy Steel Ingots and Castings in the United States—Net Tons

Year	Total Alloy Steel	Total Steel	Per Cent Alloy Steel	Tons of Total Steel to 1 Ton of Alloy Steel
1910	635,957	29,226,309	2.17	45.9
1915	1,143,685	36,009,160	3.17	31.4
1920	1,859,527	47,188,886	3.94	25.3
1925	2,724,930	50,840,747	5.36	18.6
1929	4,432,072	63,205,490	7.01	14.2
1930	2,736,508	45,583,421	6.00	16.7
1931	1,630,623	29,058,961	5.62	17.8
1932	894,436	15,322,901	5.83	17.1
1933	1,732,845	26,020,229	6.65	15.0
1934	1,805,748	29,181,924	6.18	16.1
1935	2,374,017	38,183,705	6.21	16.0
1936	3,229,657	53,499,999	6.04	16.5
1937	3,396,541	56,636,945	6.00	16.6
1938	1,653,510	31,751,990	5.21	19.0
1939	3,211,955	52,798,714	6.08	16.4

A large electric arc steel melting furnace.



(Below) Wide coils of stainless steel coming off one of the five normalizing and pickling lines in the cold rolling and stainless finishing plant of the Republic Steel Corp. at Massillon, Ohio.

(Above) An electric induction furnace at the plant of the Bethlehem Steel Co., Bethlehem, Pa.

Powder Metallurgy of Copper

PART 1

BY CLAUS G. GOETZEL

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Yonkers, N. Y.

Growing interest in the manufacture of metal products by powder metallurgy has emphasized the dearth of useful published data on the production factors involved. Engineers will therefore welcome the specific information given in this article concerning the effects of particle size, compacting pressure, heat treating temperature, time and atmosphere, and other manufacturing variables on the shrinkage, density, porosity, hardness, tensile properties, fatigue strength, etc., of copper compacts. Copper itself is a very widely used constituent of commercial powder metallurgy products, so that the data given here will have considerable direct utility. In addition many of them can be applied to powder practice in general, because of the fundamental tendencies revealed. A very important feature of the author's work is the information on, and evaluation of hot compressing (simultaneous pressing and sintering) given by him. This article is considerably condensed from the author's Ph.D. thesis at Columbia University.—The Editors.

THE PROPERTIES OF THE PRODUCTS made by powder metallurgy are affected by the particle size, shape and nature of the original powder, the pressure and conditions of pressing the compact, and the time, temperature and atmosphere of sintering. Such variables, although herein reported for copper only, are too little understood in relation to the whole field of powder metallurgy, and light thrown on the restricted topic may somewhat illuminate the entire subject.

Consolidation of copper powder for commercial purposes is possible only if pressure and heat are applied, either by applying both simultaneously, which implies a hot-compression process; or by applying one after the other, a process requiring an initial cold compression and a subsequent heat treatment. Both types of processing were used in this research, the methods and equipment having been based chiefly on European research in non-ferrous powder metallurgy.[1-11] In the case of the combined pressure and heat process, an apparatus was developed which assured the proper execution of the process. Its construction was based on the previous experience of Trzebiatowski,[9] as reported by him. For the separate application of pressure and heat, more standardized equipment was used, which permitted much flexibility in processing the compacts.

In general, an attempt has been made to obtain conclusive data on the physical properties of compacted copper powders manufactured and heat-treated by various methods. In testing the compacted copper powders, standard testing methods and specifications were approached as closely as possible, but quite frequently the compacted material required methods of testing different from those usually applied to "gross" metals. In these cases, the testing methods adopted were carefully verified in order to eliminate any doubt as to their accuracy. In testing the density of the compacts, for example, the special method used was found to be good to 0.1 per cent. The equipment used for the tensile, compressive and impact tests was of standard type[12, 13]; but for the fatigue tests, special equipment was used to give relatively accurate results in a comparatively short period of time.[14, 15]

Processing Methods

Four series of test specimens were made for this investigation. The first was made by a single compression and heat treatment of the compacts. The second series of specimens, after sintering, was repressed to the pressure used initially. Some of this series were tested in the repressed condition; others were re-sintered, or annealed, before testing. The third series of specimens was compressed at high temperatures, and the fourth consisted of wire samples produced from powder compacts.

For the first two series, compression of the powders was carried out in hardened steel dies. The compacts were molded into a shape suitable for test-

Articles

Preparedness and Defense

Three editorials deal with subjects of paramount interest to American defense—possible substitutes, manganese, and research—all vital in the present discussion of problems dealing with preparedness.

Titanium in Airplane Steel Tubing

Pronounced interest pertains just now to any article dealing with airplanes. Some reported difficulties in welding Cr-Mo steel tubing for airplanes are claimed by Mr. Comstock to be overcome by adding Ti to such steels. The aim is to improve their ductility and weldability.

Electric and Alloy Steels

A study of statistics often brings out definite trends. Some new records were made in both electric, stainless and alloy steel in 1939—particularly in electric.

Powdered Copper

Rapidly forging to the front is interest in powder metallurgy. Dr. Goetzel, in the first of a two-instalment article, discusses some of the problems of the powder metallurgy of copper. These include the effects of particle size, pressures used, heat-treating temperatures, and so on.

Copper in Cast Iron

The article by Barlow is further evidence that copper is an alloying element of value in cast iron as well as in steel. This is the first of two instalments. Emphasizing that copper is comparatively a newcomer as an alloy addition to cast iron, the discussion shows the effect of copper on irons of varying carbon, silicon and alloy content.

Lead Foil for Screens

Lead foil because of its pliability is often a problem when used for screens in the radiographing of materials. Solutions of this problem are offered by the Kodak Research Laboratories.

Surface Working Small Specimens

A novel work-hardening apparatus for producing a worked surface on specimens, developed at Battelle, is of interest. It is used in some electron diffraction investigations.

Digests

A Million Tons of Rails Tell the Story

Shatter cracks and transverse fissures in rails have caused accidents and loss of equipment but J. F. Woschitz (page 88) tells how controlled cooling eliminates these troubles and gives the experience with over a million tons of rails in service to prove it.—O. E. H.

Continuous Casting

Interest in continuous casting has picked up steam like the Willkie boom in recent months. What the eventual fate of either will be is a moot question at this writing, but prospects look good for both. A composite on page 66 concisely reviews the present status of the various casting-rolling methods so far tried.

Tinless Bearings

Since tin is one of the metals that American engineers may have to do without in time of war, a composite (page 100) reviewing German attempts to develop lead-base and aluminum-base bearing alloys using little or no tin is timely.

Aircraft Metallurgical Engineering

America's future position, and perhaps the ultimate world political situation, may depend on the American aircraft manufacturing industry as much as any other single factor. And in no other industry are metals and the metallurgical engineer so vital to success. Witness digests this month on aircraft engine valves (page 96), stainless in aircraft (page 98) and aluminum aircraft fuel tanks (page 104) plus others on magnesium castings (page 75), heat treating of aluminum alloys (page 93), deep drawing aluminum (page 94) and bearing alloys (page 100).

"Coalesced" Copper

Semi-fabricated oxygen free copper shapes are now commercially produced by heat treatment and extrusion of high purity "brittle" cathode briquettes in a controlled atmosphere (page 78).—G. L. C.

Stainless Steels

Recent improvements in the properties of stainless steels and some interesting reasons for their specific applications in various industries are discussed in a composite on page 98, indicating where stainless is used and why.

REVERE IS READY WITH THE 3 M's for "M-DAY"

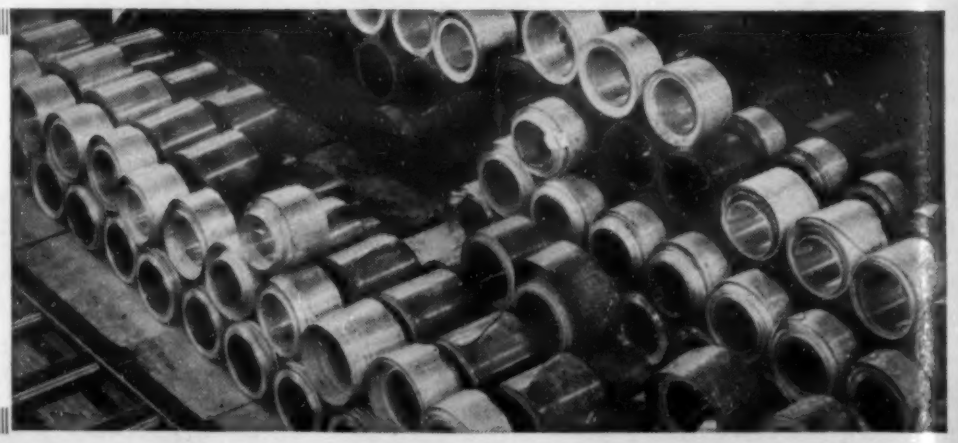
In a time of common sense and calm, years ago, the War Department of the United States foresaw that there might arise a grave national emergency when the power of America must be swiftly and efficiently marshalled for the protection of the land, its peoples and its customs. Calmly, a plan for marshalling America's might was worked out in detail. It is called the "M-Day" plan.

In this plan, every man has a role—every industry a duty.

In common with every man and woman to whom America is dear—in common with the whole of American industry—Revere Copper and Brass Incorporated profoundly hopes there will be no "M-Day"—but is ready with the three essentials for its success.

...*the* METALS

Since its founding by Paul Revere in 1801, Revere Copper and Brass Incorporated has amassed industry's most complete file of vital data on copper and its hundreds of alloys. In this file are thousands on thousands of practical facts—proved by exhaustive research in both laboratory and field. From this vast storehouse of metal lore, government and industry are able to know more swiftly and more surely which metal is most efficient and most economical for the purpose.



...*the* MEN

Typical of the spirit of 8,000 Revere men are these skilled craftsmen. The one at the right, has been a Revere man all his working life. Long ago, Revere recognized the importance of *trained man-power* to national security. Its organization includes a Technical Advisory Service of experienced engineers to help analyze individual requirements of a problem—a Methods Staff, to insure rigid adherence to specifications—and, above all, a loyal corps of skilled workers to get the work done right and done quickly.

In publishing this advertisement in the New York Times, June 11, 1940, Revere feels it was speaking for the men as well as the management of all American industry.

...*the* MACHINES

In the past few years, Revere has invested millions of dollars in modernizing its many mills—even inventing its own machines to abolish "bottle-necks" and produce better products. This expansion enables material to flow through in minimum time with maximum control of quality. Heavy muscular labor has been largely eliminated, with a resulting increase in safety as well as capacity.

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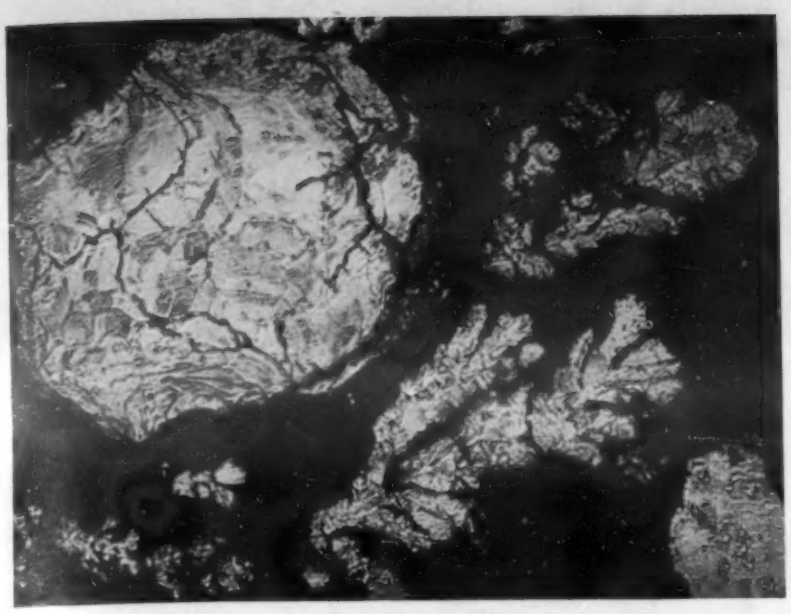


Fig. 1. Electrolytic copper powder A, before compression. X200.

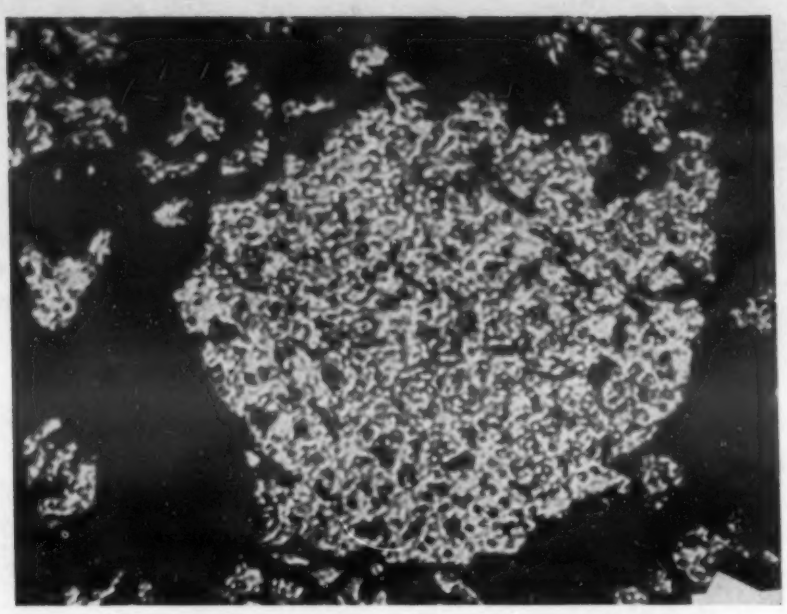
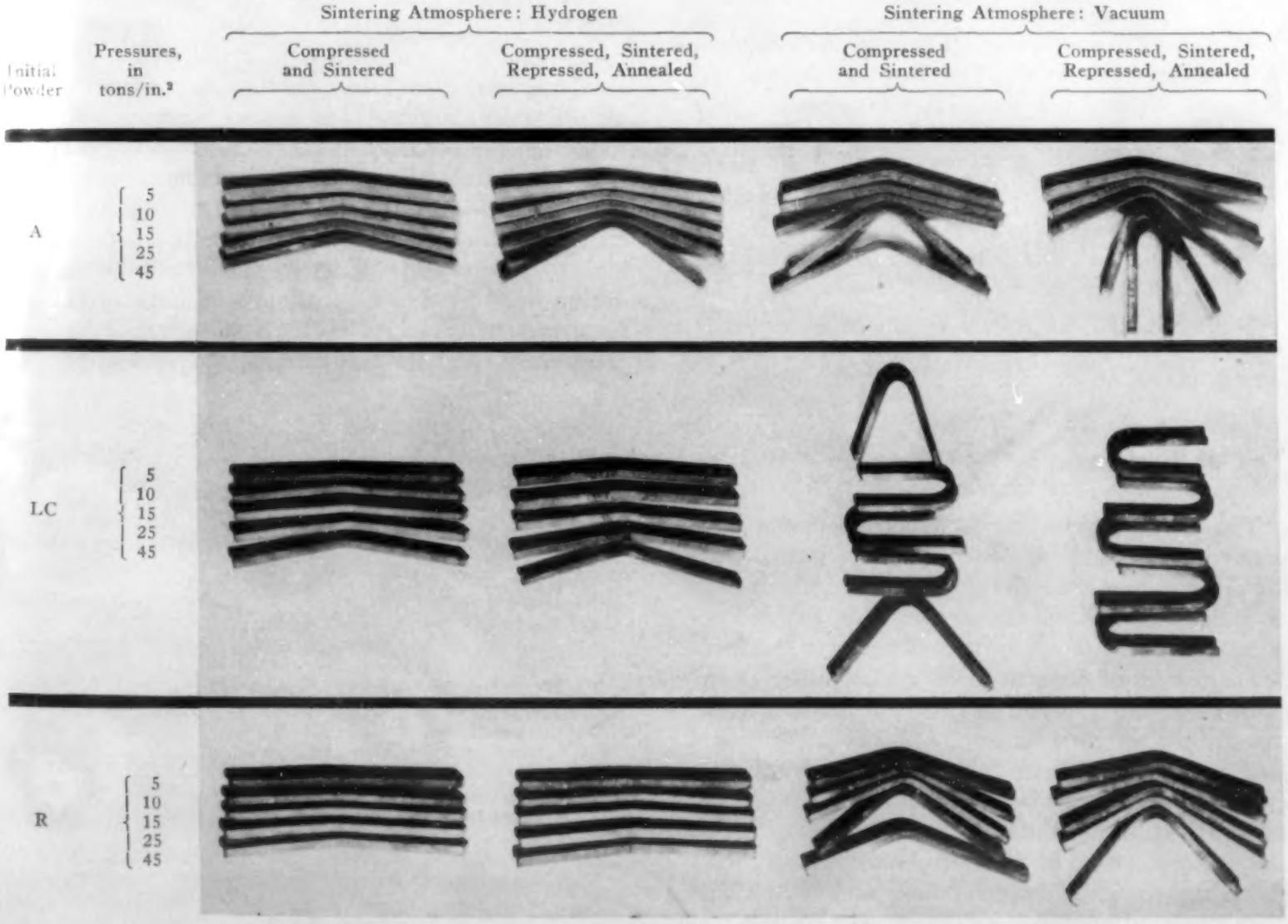


Fig. 2. Reduced copper powder R, before compression. X1000.

Fig. 3. Bending test specimens from powder compacts, after testing. All specimens were 3 in. x 3/8 in. x 1/8 in., and were bent until the first crack became visible or until a bending angle of 180 deg. was reached.



ing, which made subsequent machining superfluous. The pressure was varied from 5 to 190 tons per sq. in., and was applied by a 50-ton Watson-Stillman hand-operated hydraulic press, or by a 600,000-lb. Southwark-Emery hydraulic testing machine. Sintering and annealing operations were carried out in a tubular electric resistance furnace. The specimens, supported by plates, were placed into a fused silica tube, and this was carefully closed and sealed. This furnace made possible heat-treating in any desired atmosphere as well as in vacuum.

The hot compression equipment could be operated at temperatures up to 500 deg. C., and was fitted for compression of the compacts in a reducing atmosphere. Pressure, varying from 5 to 50 tons per sq. in., was applied by means of a 25-ton Carver hand-operated hydraulic press. Heat was supplied by an electric furnace surrounding the die. The die itself was made of W-Cr-V high-speed steel, which retains its hardness up to 500 deg. C. The temperature was measured by an iron-constantan thermocouple, the junction of which was brought as close to the specimen as possible.

Wires were made only from sintered compacts. Each compact was divided into two parts; one part was subjected to reduction by cold rolling without intermediate annealing; the other was annealed several times during the reduction. After a reduction in area of approximately 97 per cent by cold rolling, the wires were drawn through a draw-plate without intermediate annealings. The wires, as rolled, had a square section, but this was transformed into a round section, 0.060 in. in diameter, by 12 passes through the draw-plate (47% reduction in area). Half of the length of the finished wires was left in the hard drawn condition; the other half was annealed in an electric furnace at 600 deg. C. for 1 hr. If the initial compacts were sintered in hydrogen, the wires were annealed in hydrogen; similarly, wires produced from compacts sintered under vacuum were annealed under vacuum.

Type of Powder

Two kinds of copper powder, electrodeposited and reduced, were used for making test specimens. All the powders were reduced at 300 deg. C. for 2 hrs. in a steady stream of commercial hydrogen before being compacted to specimens. The dry electrolytic powders were of four standard grades, differing in particle size and apparent density. In this work they are designated by symbols "A," "B," "C" and "LC"; A is the coarsest; LC, the finest and lightest. The powder produced by reduction of copper oxides with carbon monoxide was of a medium particle size; it is designated in this work by the symbol "R." The characteristics and specifications of the powders used are given in the Table. Figs. 1 and 2 show the size and shape of representative powder particles.

The influence of the type, particle-size range, and shape of the copper powder particles on the properties and microstructure of the finished products may be summarized as follows:

Electrolytic powder particles generally showed greater resistance to deformation upon compacting than the reduced powder, probably because of the nodular arrangement of their component crystallites. Compacts made from electrolytic powders generally had better physical properties, including impact strength and fatigue resistance. It is likely that the shape and arrangement of the component crystallites are not the only reasons for such a general difference in the results, for the conditions at the grain boundaries and the kinds of impurities play an important part throughout the manufacture of the powder compacts.

The reduced powder particles, which had more regular shapes and were more uniform in size, tended to flow under pressure and were more easily deformed. This fact could be noticed in cold compacted specimens, as well as in hydrogen-sintered material after cold rolling. Compacts of this powder, however, were usually inferior in their physical characteristics, the single exception being hardness.

The grain structure of the compacts depended largely upon the original particle size of the powders used. Fine powders resulted in a uniform and exceedingly fine structure, whereas coarse powders yielded a less uniform and coarser structure. This influenced the behavior of the final products. Compacts from coarse powders showed superiority in rolling into wire, and also in all the mechanical and electrical tests on wires. Such compacts possess higher density and conductivity, and shrink less during heating. Their superiority in impact resistance may be explained by the fact that their total grain surface is less, and therefore the weakest part

Table of Types of Copper Powders Tested

Symbol	Type of Powder	Grade	Apparent Density (Loading Weight) (gms./cm.³) Used Powders	Apparent Density (Loading Weight) (gms./cm.³) Specification
A	Electrolytic dry	Very coarse particles, finer particles in small proportion...	3.49	4.0—4.5 2.5—2.8
B	Electrolytic dry, commercial	Mixture of coarse and fine particles	2.57	2.5—2.6
C	Electrolytic dry, commercial"	Majority of fine particles with very few coarser particles...	2.14	1.8—2.5
LC	Electrolytic dry, commercial	Fine particles, lower apparent density...	1.44	1.2—1.5
R	Carbon monoxide reduced dry, commercial	Uniform medium size of particles	2.37	2.33

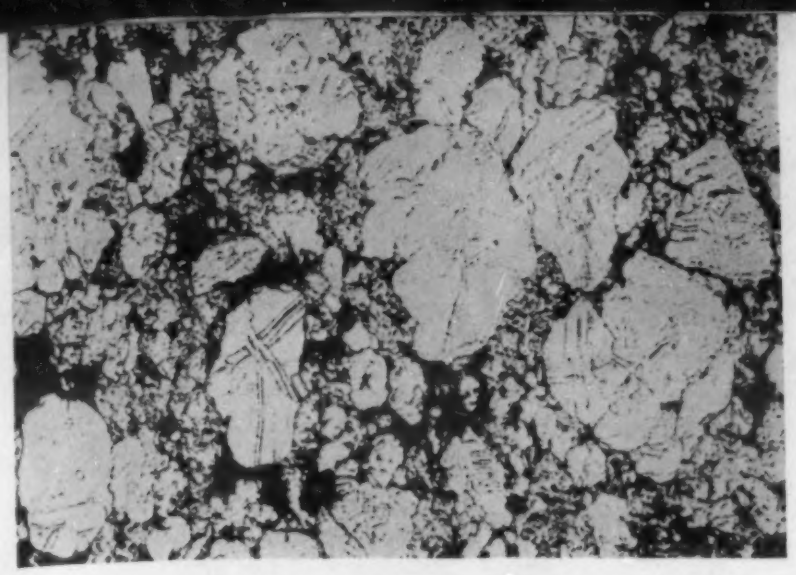


Fig. 4. Electrolytic copper powder B, compacted at 45 tons per sq. in., not sintered. X200.

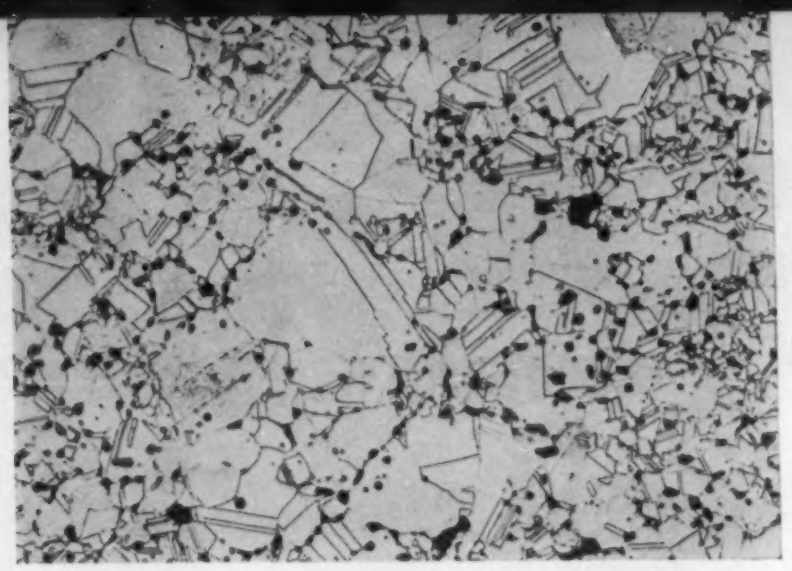


Fig. 5. Electrolytic copper powder B, compacted at 45 tons per sq. in., sintered at 750 deg. C. for 16 hrs. in hydrogen. X200.

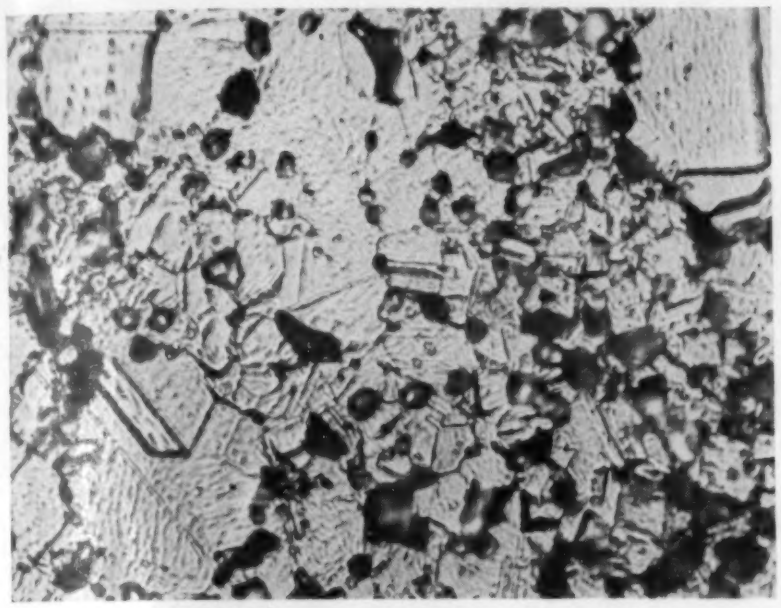


Fig. 6. Electrolytic copper powder B, compacted at 45 tons per sq. in., sintered at 750 deg. C. for 16 hrs. in vacuo. X1000.

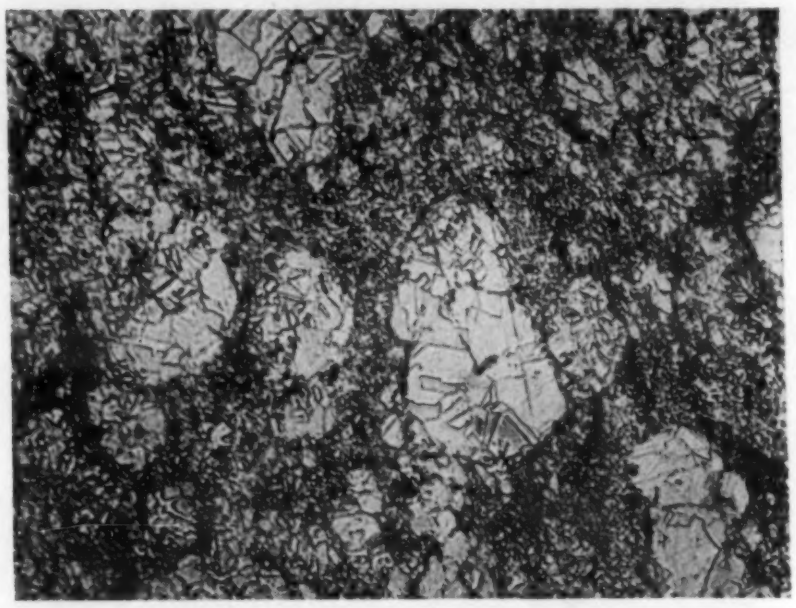


Fig. 7. Electrolytic copper powder B, hot-compressed at 400 deg. C. at 50 tons per sq. in. in hydrogen. X200.

of the sintered compacts, namely the grain boundary area, is smaller than that of compacts made from fine powders. On the other hand, compacts prepared from fine powders were superior in tensile strength, elongation, compressive strength, hardness and fatigue resistance. Only bending tests (see Fig. 3) on solid compacts, imposing a complex stress on the specimens, show no consistent influence of the particle size of powder; hydrogen-treated compacts of the coarse powders gave larger bending angles than similarly treated fine particles. The reverse behavior was observed when vacuum treatment was applied.

Structural Consolidation

The type of final grain structure is largely dependent upon four factors: (1) the type and fineness of the initial powder, the effect of which has already been mentioned, (2) the temperature of heat treatment, (3) the duration of the heat treatment, and (4) the atmosphere in which the heat treatment was carried out. The application of compacting pressure has only an indirect bearing on the final grain structure of the compacts because it merely condenses the loose particles to more or less porous briquettes as shown in Fig. 4. The porosity remaining in these briquettes after compression governs the structure of the final compacts to a certain extent. Grain growth may close or change some of the cavities, but this is largely dependent upon one or more of the above-mentioned four conditions.

Metallographic examination gave a definite answer to the question of the effect of the temperature and time at which "recrystallization" of the copper powder compacts was completed, and the results of the physical tests confirmed these conclusions. The properties of the compacts could be improved but little by processing at temperatures in excess of, or for periods longer than those found necessary for the formation of the characteristic polyhedral structure (750-900 deg. C., and 16 hrs.). The improvement in the physical properties was always rapid up to the point at which the consolidation of the metal was essentially completed (Fig. 5); beyond this point further improvement was slow. However, even incompletely diffused material, such as the hot compressed compacts molded at 400 deg.

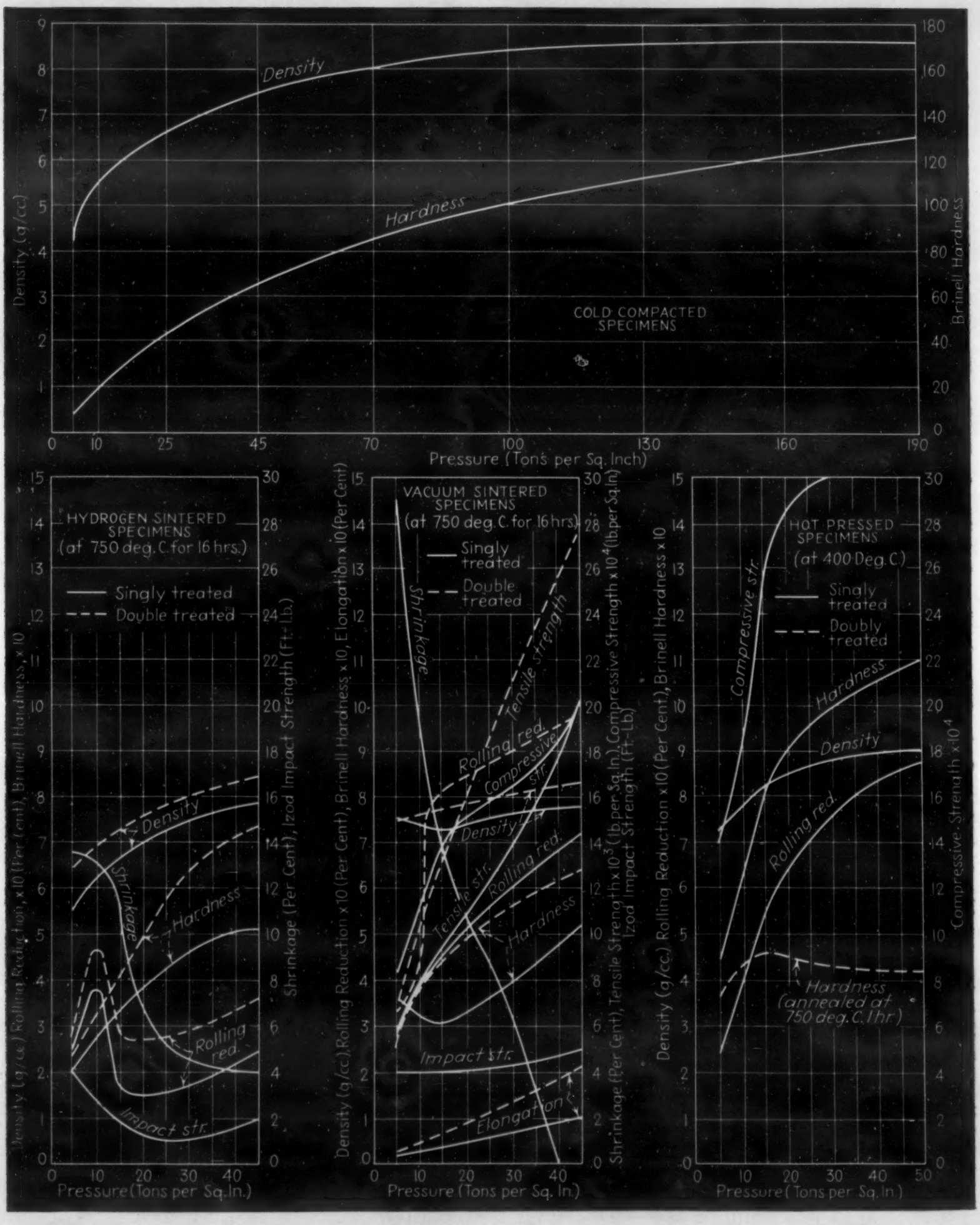


Fig. 8. Effect of pressure on the properties of compacts made from electrolytic copper powder C.

C., whose structure is shown in Fig. 7, yielded good characteristics, such as high hardness, compressive properties, and rolling ability.

The atmosphere in which the compacts are heated is of particular importance; the consolidation, which involves both recrystallization and grain growth, can take place without hindrance only if the impurities, such as oxides or carbonaceous residue, are removed to a great extent by a suitable heat-treating atmosphere.

Porosity

The porosity influences grain growth and therefore the size of crystals in the final structure. This fact has its bearing on the physical properties of the material, such as density, malleability, conductivity, impact resistance, and tensile strength, which are chiefly dependent upon the structure of the final product. Furthermore, there is a direct relationship between porosity and the properties of the final compacts.

Microscopic examination disclosed that there are two types of porosity in sintered compacts. The first kind, which may be called "primary" porosity (illustrated in Fig. 4), is due to imperfect compacting and can be controlled to a certain extent by changing basic conditions, such as type and particle size of powders, compacting pressure or shape of the specimens. This kind of porosity has a detrimental effect on the quality of the final compacts, because the cavities usually are angular and more or less continuous. Only reduction of their size and increasing their separation can counteract this effect. Subsequent heat treatment usually provides a good means of compensating for the detrimental action of this "primary" porosity by causing diffusion and grain growth of the particles, as exemplified by the structure of Fig. 5.

The other type, which may be called "secondary" porosity, is of equal importance. This porosity is developed during heat-treatment because of gas evolution, and is influenced chiefly by two conditions: (1) the particle size of the powder and (2) type of heat treating atmosphere. The finer and lighter powders adsorb more gases and entrap more air during compacting, and more gas is expelled during heating. If the gas is evolved by heating at atmospheric pressure it escapes at a rather slow rate; and with sufficient time permitted for its complete expulsion, diffusion and shrinkage of the metallic sponge will diminish the porosity. The situation, however, is different when heat-treating is carried out under vacuum (see Fig. 6). During the initial stage of the heat treatment a large amount of gas was evolved, and on the other hand, the microstructure showed a large amount of new, "secondary," cavities which were observed neither in the compacted powders, nor in hydrogen-sintered specimens. Also, the density decreased in the compacts after their treatment in vacuum.

Repressing of the compacts subsequent to their heat-treatment had an important effect on the porosity. Although it does not eliminate the pores entirely, it reduces them, and condenses the compacts. This is the main reason that almost all the physical properties of the compacts increased markedly after a second processing, as demonstrated in Fig. 8.

The results of the physical tests gave many illustrations of the beneficial influence of a well-distributed microscopic porosity such as is found in the vacuum-treated specimens, as compared to the odd-shaped porosity of low-compressed and hydrogen-treated specimens. Malleability and ductility are much influenced by this fact, as was proved by the results of the rolling, drawing and especially the bending tests (Fig. 3).

Hot compressed compacts, with almost a complete lack of cavities, yielded excellent physical qualities, such as hardness and compressive strength, and, despite insufficient grain-size development, even permitted direct cold rolling to wire size (as did the cold-pressed and long sintered specimens, naturally). These results are discussed more fully in a subsequent section. *(To be concluded)*

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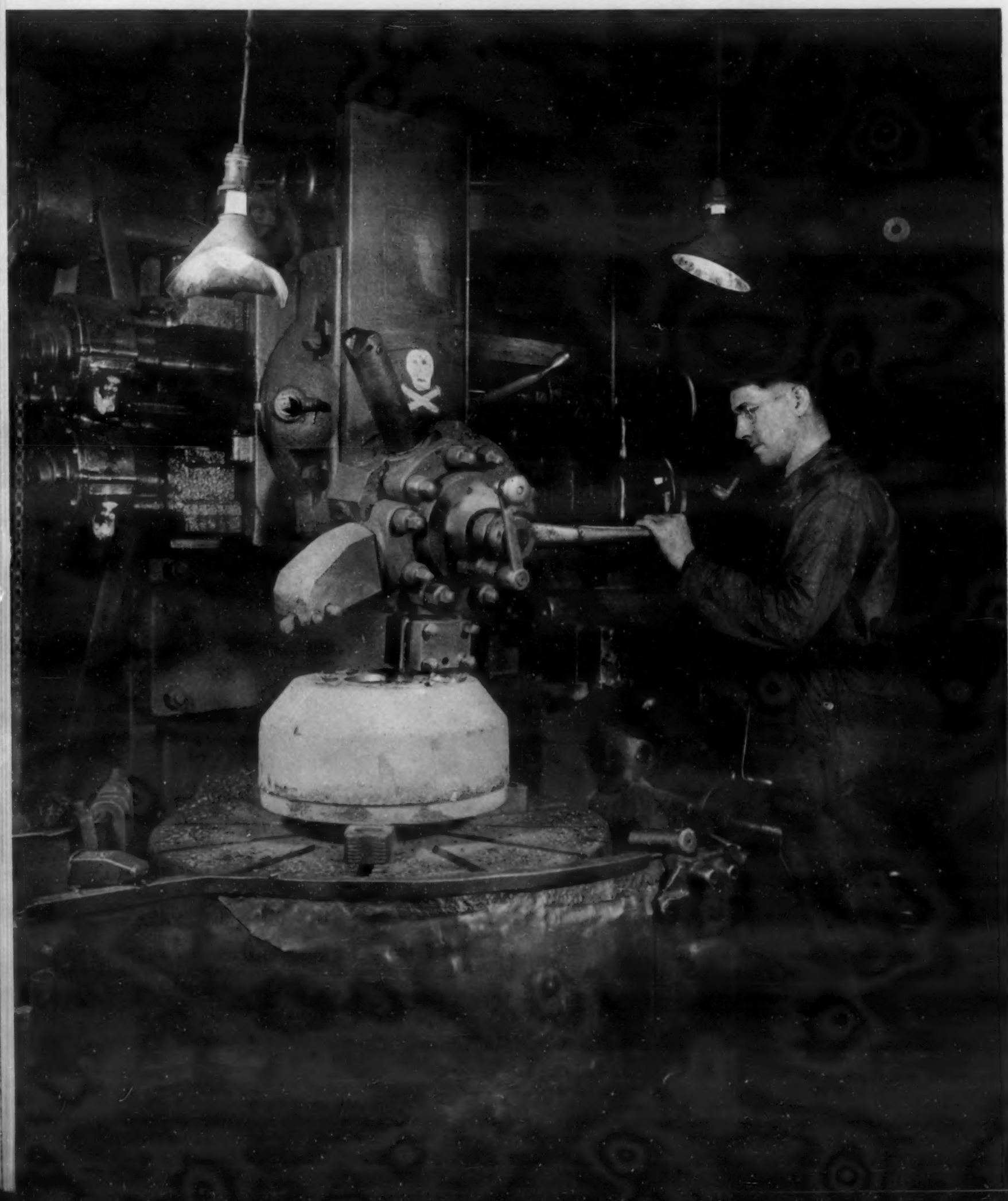
Electric Furnace Cast Irons Co

Machining an electric furnace copper-molybdenum cast iron truck brake drum. This brake drum must demonstrate excellent wearing properties, resistance to heat checking, and good machinability with a minimum tensile strength of 50,000 to 55,000 lbs. per sq. in. (Courtesy: Dayton Steel Castings Co.)



ns Containing Copper—Part 1

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Copper, Iron and Steel Development Ass'n.,
Cleveland

Despite their fast-growing application for such products as cylinder blocks, heavy duty brake drums, pumps, large gears, etc., copper alloy cast irons as a class have not heretofore been subjected to any comprehensive examination of their mechanical properties in the various compositional combinations possible. Copper in cast iron has been recognized as a mild graphitizer and chill reducer with pronounced densening effect—an alloy addition with a favorable influence on both machinability and strength. It sometimes appears also to be peculiarly and disproportionately beneficial when present along with carbide-formers like chromium, molybdenum and vanadium.

This article reduces all this qualitative information to fact, shows the effect of copper in cast irons of varying carbon, silicon and "other alloy" contents, and permits the foundryman and engineer to select compositions of copper cast irons that give the most desirable combinations of properties for specific types of service.—The Editors.

KNOWLEDGE OF THE EFFECTS of the different alloying elements on the structure and properties of gray cast iron is steadily increasing as the result of extensive study by the producers of these elements, as well as by the foundries themselves. The use of individual alloying elements to improve the properties of gray cast irons is well established. The tendency today is to pay close attention to carbon and silicon contents and to strive for a balanced composition, using, if necessary, two or more alloying elements in combination, to obtain the desired results in the most economical manner.

Copper is a comparative newcomer in the small group of elements used commercially as alloy additions to cast iron. The successful experience of the Ford Motor Co., the Allis-Chalmers Mfg. Co. and several other large foundries where copper has been used for years has attracted widespread attention. Systematic engineering data are needed, however, so that the foundryman interested in the production of copper alloy cast irons can apply this commercial experience in his own practice over a wide range of engineering irons.

Recognizing this need, the copper industry is conducting a long-time program of research and development at Battelle Memorial Institute. This article is based upon unpublished progress reports of this work by C. H. Lorig and E. C. Kron of Battelle Memorial Institute and the tables of data are taken from these reports.

As part of this program, an investigation was made of the effects of copper on the properties of gray cast irons of different carbon and silicon contents. These experiments were planned to cover a wide range of compositions so that an indication of the interrelations of the copper, carbon and silicon contents might be obtained. An indirect arc electric furnace was used as a convenient means of producing the irons under carefully controlled conditions.

The melts were heated to about 2800 deg. F. in the furnace, poured into ladles and held until the temperature had dropped to 2550 deg. F. before casting.

The information obtained is useful as a guide for ordinary cupola practice but the numerical values for the various properties of the different irons may of course be somewhat different for cupola metal. It is planned to supplement these results with a similar investigation of the more useful copper alloy cast irons as made in the cupola under shop conditions.

Four series of cast irons were prepared. These are (1) high-carbon, containing from 3.30 to 3.44 per cent C and 0.63 to 2.50 per cent Si; (2) medium-carbon, with 3.07 to 3.20 per cent C and 0.68 to 2.61 per cent Si; (3) low-carbon, with 2.80 to 2.90 per cent C and 1.09 to 2.52 per cent Si; and (4) alloyed, containing from 3.12 to 3.23 per cent C, and 1.48 to 1.74 per cent Si with various combinations of nickel, chromium, molybdenum and vanadium.

The effect of copper in amounts up to 3 per cent in each of these series was studied. The mechanical properties of the irons, that is, the tensile and transverse strengths, the deflection, the resilience, the Brinell hardness and the impact resistance were determined for 4 different casting sections, represented by test bars 0.875, 1.2, 2.0 and 4.0 in. in dia.

Values were obtained from duplicate bars in all cases. Two tensile bars were cut from each 4-in.

test bar. The Brinell hardnesses were taken midway between the center and the surface of all bars. The unnotched impact values were determined with a Charpy type machine on the broken halves of the 0.875 and 1.2-in. dia. test bars.

In this way, a measure of the influence of section size on the effects of copper could be indicated.

High-Carbon Cast Irons

The results on the high-carbon series (3.30-3.44 per cent C) are shown in Table I. The effects of copper on the properties of the 1.00 to 1.09 per cent and the 1.38 to 1.52 per cent Si grades in the 4 sections are plotted in Fig. 1.

The trend in properties with copper content appears to be characteristic for each silicon group of the series. The trend in tensile strength, transverse strength and Brinell hardness is upward with increasing copper contents. The deflection is affected only slightly, in general trending toward lower values as the copper content is increased. The influence of copper is equally effective in the 4 sizes of test bars. *(To be concluded)*

TABLE I. The Compositions and Mechanical Properties of the High-Carbon Cast Irons of Varying Silicon and Copper Contents

Battelle Heat No.	Bar No.	Composition, Per Cent	Cast Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4753	1	C -3.44	0.875	.....	.....	....	.....	...	...	..
		Si -0.63	1.2	35,000	3,100	0.290	82,000	46	199	39
		Cu-0.00	2.0	32,500	9,700	0.392	74,000	211	180	..
			4.0	34,500	.....	....	.....	...	186	..
4753	2	C -3.43	0.875	.....	2,200	0.169	100,000	17	...	15
		Si -0.63	1.2	41,000	3,300	0.313	88,000	53	216	42
		Cu-0.99	2.0	40,000	10,400	0.318	79,000	168	203	..
			4.0	39,000	.....	....	.....	...	206	..
4753	3	C -3.41	0.875	52,000	2,250	0.172	103,000	18	256	16
		Si -0.63	1.2	52,500	3,350	0.277	89,000	44	240	47
		Cu-1.83	2.0	48,500	11,200	0.316	86,000	173	226	..
			4.0	.....	.....	....	.....	...	240	..
4754	4	C -3.37	0.875	.....	1,450	0.091	66,000	6	...	9
		Si -1.00	1.2	40,500	2,850	0.321	76,000	49	205	56
		Cu-0.00	2.0	34,500	9,300	0.346	71,000	172	194	..
			4.0	40,000	.....	....	.....	...	229	..
4754	5	C -3.36	0.875	51,500	2,000	0.176	92,000	17	250	15
		Si -1.07	1.2	45,500	2,900	0.261	77,000	37	221	38
		Cu-1.00	2.0	40,000	9,900	0.292	75,000	144	216	..
			4.0	38,000	.....	....	.....	...	219	..
4754	6	C -3.32	0.875	52,500	1,950	0.152	88,000	13	257	14
		Si -1.09	1.2	49,000	2,950	0.243	78,000	33	245	37
		Cu-1.72	2.0	39,000	10,300	0.275	78,000	134	223	..
			4.0	35,000	.....	....	.....	...	203	..
4758	12	C -3.36	0.875	56,500	2,350	0.210	106,000	24	241	17
		Si -1.09	1.2	49,000	3,850	0.312	102,000	56	259	44
		Cu-2.09	2.0	41,500	10,300	0.287	79,000	142	221	..
			4.0	47,500	.....	....	.....	...	233	..
4759	13	C -3.39	0.875	55,000	.....	....	.....	...	262	15
		Si -1.08	1.2	51,500	3,450	0.300	92,000	49	244	46
		Cu-3.01	2.0	43,500	10,700	0.289	81,000	143	230	..
			4.0	51,000	.....	....	.....	...	236	..
4756	9	C -3.32	0.875	44,000	1,800	0.182	81,000	16	215	19
		Si -1.38	1.2	45,000	2,850	0.308	76,000	46	208	42
		Cu-0.00	2.0	37,000	9,400	0.356	72,000	179	197	..
			4.0	35,000	.....	....	.....	...	208	..
4756	10	C -3.30	0.875	48,000	1,850	0.167	84,000	18	225	16
		Si -1.42	1.2	45,500	2,900	0.281	77,000	41	213	40
		Cu-0.53	2.0	36,000	9,600	0.307	74,000	147	203	..
			4.0	37,000	.....	....	.....	...	197	..
4756	11	C -3.30	0.875	48,000	1,900	0.156	87,000	15	236	15
		Si -1.41	1.2	46,000	3,050	0.270	80,000	40	220	40
		Cu-0.95	2.0	37,000	10,400	0.317	79,000	163	210	..
			4.0	36,500	.....	....	.....	...	197	..
4757	14	C -3.34	0.875	49,000	2,050	0.183	94,000	18	236	17
		Si -1.49	1.2	48,500	3,200	0.301	85,000	47	228	42
		Cu-1.56	2.0	38,500	9,900	0.297	76,000	142	215	..
			4.0	43,000	.....	....	.....	...	222	..
4757	15	C -3.39	0.875	51,000	2,150	0.192	97,000	19	243	17
		Si -1.52	1.2	46,000	3,200	0.303	85,000	47	228	46
		Cu-2.01	2.0	40,500	10,000	0.313	79,000	156	216	..
			4.0	44,000	.....	....	.....	...	222	..

Battelle Heat No.	Bar No.	Composition, Per Cent	Cast Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4759	16	C -3.33	0.875	44,500	1,750	0.217	80,000	20	202	19
		Si -1.72	1.2	38,500	2,800	0.355	74,000	53	196	46
		Cu-0.00	2.0	34,500	9,100	0.385	69,000	191	188	..
			4.0	34,500	.....	....	.....	...	193	..
4759	17	C -3.35	0.875	47,000	1,800	0.213	83,000	20	210	16
		Si -1.74	1.2	38,000	2,750	0.335	73,000	48	202	46
		Cu-0.55	2.0	33,500	9,100	0.352	69,000	166	196	..
			4.0	36,500	.....	....	.....	...	201	..
4759	18	C -3.36	0.875	49,500	1,900	0.183	86,000	17	232	17
		Si -1.75	1.2	42,000	2,950	0.318	78,000	47	214	39
		Cu-1.09	2.0	34,500	9,300	0.299	71,000	135	204	..
			4.0	37,000	.....	....	.....	...	204	..
4760	19	C -3.36	0.875	44,000	1,700	0.215	78,000	19	203	17
		Si -1.84	1.2	36,000	2,700	0.348	72,000	51	190	48
		Cu-0.00	2.0	35,000	8,900	0.380	68,000	182	190	..
4760	20	C -3.43	0.875	44,500	1,700	0.196	78,000	17	215	16
		Si -1.87	1.2	36,500	2,700	0.311	72,000	44	199	41
		Cu-0.53	2.0	36,000	9,200	0.365	70,000	178	197	..
4761	21	C -3.36	0.875	49,000	1,950	0.206	90,000	20	231	17
		Si -1.84	1.2	42,000	2,950	0.315	78,000	47	217	40
		Cu-1.27	2.0	35,000	9,200	0.308	70,000	139	201	..
4776	60	C -3.40	0.875	33,000	1,400	0.181	63,000	12	187	12
		Si -2.50	1.2	26,500	2,200	0.314	59,000	35	175	28
		Cu-0.00	2.0	25,000	7,200	0.330	55,000	124	167	..
4776	61	C -3.41	0.875	33,000	1,400	0.170	63,000	11	197	12
		Si -2.50	1.2	25,500	2,200	0.314	58,000	35	180	30
		Cu-0.47	2.0	24,000	7,200	0.323	55,000	115	174	..
4776	62	C -3.44	0.875	29,000	1,650	0.175	75,000	14	197	12
		Si -2.47	1.2	28,500	2,300	0.276	61,000	30	198	28
		Cu-0.95	2.0	24,000	7,100	0.280	54,000	96	178	..

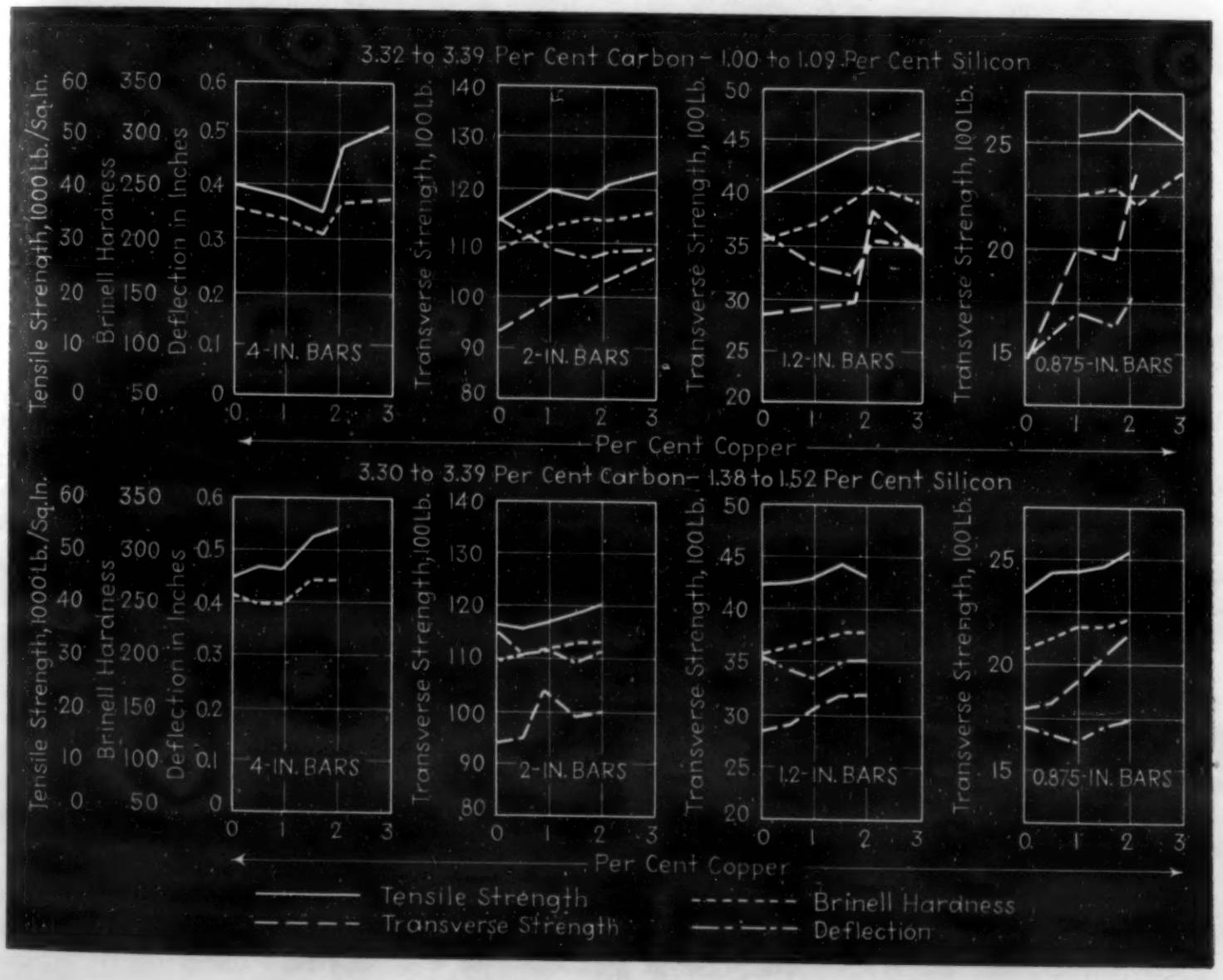


Fig. 1. The effect of copper on the properties of high-carbon cast iron.

Mounting Lead Foil for Ra

Lead foil as frequently used for screens in the radiography of materials is awkward to handle because of its excessive pliability. Mounting the foil on sheet aluminum or on cardboard gives a rigidity which facilitates handling and does not interfere with the radiographic properties. Preparation of such screens is described in detail. It is suggested that a 94 per cent lead—6 per cent antimony alloy foil be used instead of "pure" lead because it is less likely to cause artifacts on the film. Directions for the care of lead screens are given.

This is Communication No. 757 from the Kodak Research Laboratories.

IT HAS BEEN CUSTOMARY for some time to use lead foil in contact with the X-ray film in certain classes of radiography of industrial materials.[1] The time of exposure with such screens is considerably longer than when fluorescent intensifying screens are used with the same technique, but there are certain advantages in using lead foil in this manner whenever conditions permit.

The intensifying action of such screens has been shown to be due largely to the emission of electrons from the lead under X-ray excitation.[2] Some of the action is, of course, due to X-rays re-emitted by the lead, but these apparently play a minor part. With hard radiation, the decrease of exposure time is an important advantage of the lead screen.

An even more important feature is the ability to remove some of the secondary radiation which is always produced whenever X-rays strike matter. The secondary X-rays are of a diffuse nature and, hence, are non-image-forming. Their effect is to reduce the contrast in the radiographic image and therefore to render detail more obscure. This reduction of secondary radiation is caused by two principal effects: First, since the secondary radiation is, on the average, of longer wave length than the primary image-forming radiation, it is more strongly *absorbed* in the lead foil than the primary and, second, since the intensifying action of the lead foil, within certain limits, is stronger the shorter the wave length, the primary radiation will be *intensified* more than the secondary radiation. This differential intensification will, therefore, result in an improvement in radiographic quality. The combination of *differential intensification* and *differential filtration* results in a reduction of the secondary radiation effect to about one-half its original value.

Lead foil screens are recognized as probably more satisfactory than any other type for gamma-ray radiography.[3] Exposure times are nearly as short as for fluorescent intensifying screens; hence, the advantages of lead screens need not be weighed against the intensification factor of fluorescent screens. For practical purposes, radiographic definition obtained with lead screens is just as good as with film alone. No extensive study has been made of the physical nature of the action of lead screens with gamma rays but there is no reason to suppose that it is essentially different from the response to X-rays except in magnitude.

The advantages of lead foil screens are so well recognized that their use is quite wide-spread. This use, however, involves some practical difficulties. One of the most important of these is the problem of handling lead foil without damage under industrial conditions. The fact that its manipulation must be in a darkroom adds further to the problem. It is the purpose of this paper to describe methods of mounting lead foil in suitable form for use as radiographic screens.

Details of Mounting

Lead foil, 0.012 to 0.015 cm. thick for the front screen, and 0.040 to 0.060 cm. thick for the back screen, (the use of a thick back screen is a desirable precaution against back-scattered radiation), has generally been found to be satisfactory from a radiographic standpoint. Its utility, however, would be improved by mounting it on a stiff support. Experiments have resulted in a method of mounting lead foil on sheet aluminum or aluminum alloy. Such a light metal has practically no effect upon the radiographic properties of the lead but gives a mechanical rigidity which makes it easier to handle. A sheet of chemically clean aluminum alloy (52 S, hardest grade) about 0.075 cm. thick is cut to the desired size. It is then coated with Goodrich Vulcalock cement which has been thinned below its usual consistency by the addition of xylol.

(This cement may be obtained from the B. F. Goodrich Company, Akron, Ohio. It is made from Thermoprene, a patented thermoplastic, made by chemical alteration of rubber. Application should be made only in a well-ventilated room and away from sparks or flames because of the toxic and fire hazards.)

Equal parts of Vulcalock and xylol make a mixture which is easily flowed onto the metal. Excess liquid should be drained off. A sheet of chemically clean lead foil is similarly coated on one side. These are left to dry until the cement has reached a tacky consistency. Sufficient drying at this stage is important to prevent the inclusion of solvent between the aluminum and lead sheets when they are finally placed in contact. If the solvent has not evaporated, blisters may appear on the foil some time after an apparently satisfactory screen has been completed. A suitable mechanical device for forcing the two elements in

for Radiographic Screens

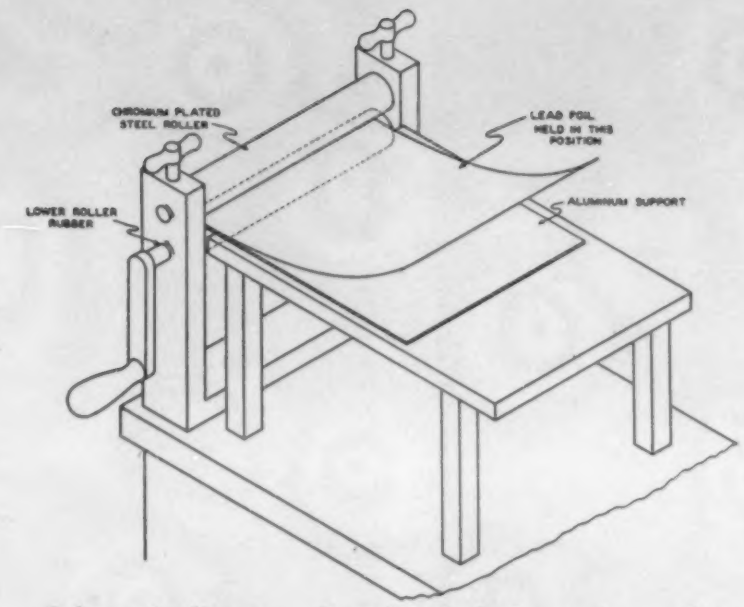
intimate contact was constructed by replacing the upper roller of a common clothes wringer with a polished chromium-plated steel roller of the same size. This roller bears on the foil element and tends to produce a smooth surface. The lead foil is placed in contact with the aluminum sheet *along one edge only* and this edge is introduced into the wringer. While the wringer is turned *slowly,* the free lead foil is held carefully above the remaining aluminum. If the lead foil is not so guided, the two sheets are liable to adhere irregularly and the pressure of the rollers will introduce wrinkles in the foil. Passing the two sheets through the wringer slowly several times, always in the same direction, results in a very secure bond between the two metals.

Cleanliness and extreme care in the entire process are quite important if the finished product is to be of pleasing appearance. All irregular deposits of cement or particles of dirt included between the two metals are sure to appear as irregularities on the finished surface. If they are *small,* there is little chance that they will have any detrimental effect on the radiographic image. Small particles on the polished roller, or on the top surface of the foil, will produce dents in the surface which again, if small, will not be of serious consequence in the radiographic image. Both metals should be free from oil or grease to insure good bonding. The edges of the finished screens may be improved by rounding slightly with a fine file, moving the file always from the lead toward the aluminum.

As in the case of the use of any intensifying screen, good contact between the screen and the film is important. Therefore, very flat aluminum sheets are to be desired as a base for lead screens. They may, of course, occasionally have a slight curvature which is of no consequence when they are placed in a cassette which can exert sufficient pressure over the whole area of the screens to insure good contact with the film.

Another Method of Mounting

A simpler method for mounting the lead, but one which results in a less durable product, is to coat the lead and a piece of smooth, 0.1 cm. Bristol board with ordinary shellac. This is permitted to dry to a tacky consistency. The lead foil is now laid upon



Schematic diagram of modified clothes wringer showing method of introducing foil and support between the rollers.

the Bristol board and smoothed out a little with the palm of the hand. The screen should then be trimmed so that neither element will have any coated parts exposed to contaminate the rollers. The unit is introduced into the wringer and rolled through slowly a few times. This method does not require the use of a steel roller, the common clothes wringer being satisfactory as it is. Bubbles of solvent vapor are not likely to cause blisters in this method because of the permeability of the cardboard component. It is obvious that the cardboard-mounted screen will be more subject to damage than the metal-mounted screen, but relatively little effort is needed to make the cardboard mounting, and lead foil is cheap enough so that when such a screen is finally damaged it may be thrown away.

An Alloy Lead for the Foil

In the foregoing discussion, the foil has been referred to as "lead" foil. There is little doubt that lead is the most satisfactory metal for the active component of a metallic screen. One of its unfortunate properties is that it may rub off onto an X-ray film and so cause a disturbing artifact. An alloy of 94 per cent Pb and 6 per cent Sb (supplied by the Standard Rolling Mills, Inc., 143 Jewel St., Brooklyn, N. Y.) has shown less tendency to smear than "pure" lead, and also exhibits better mechanical properties. The small percentage of antimony has no practical influence on the radiographic characteristics of the lead component. It must be emphasized that a coating of tin or any other material on the

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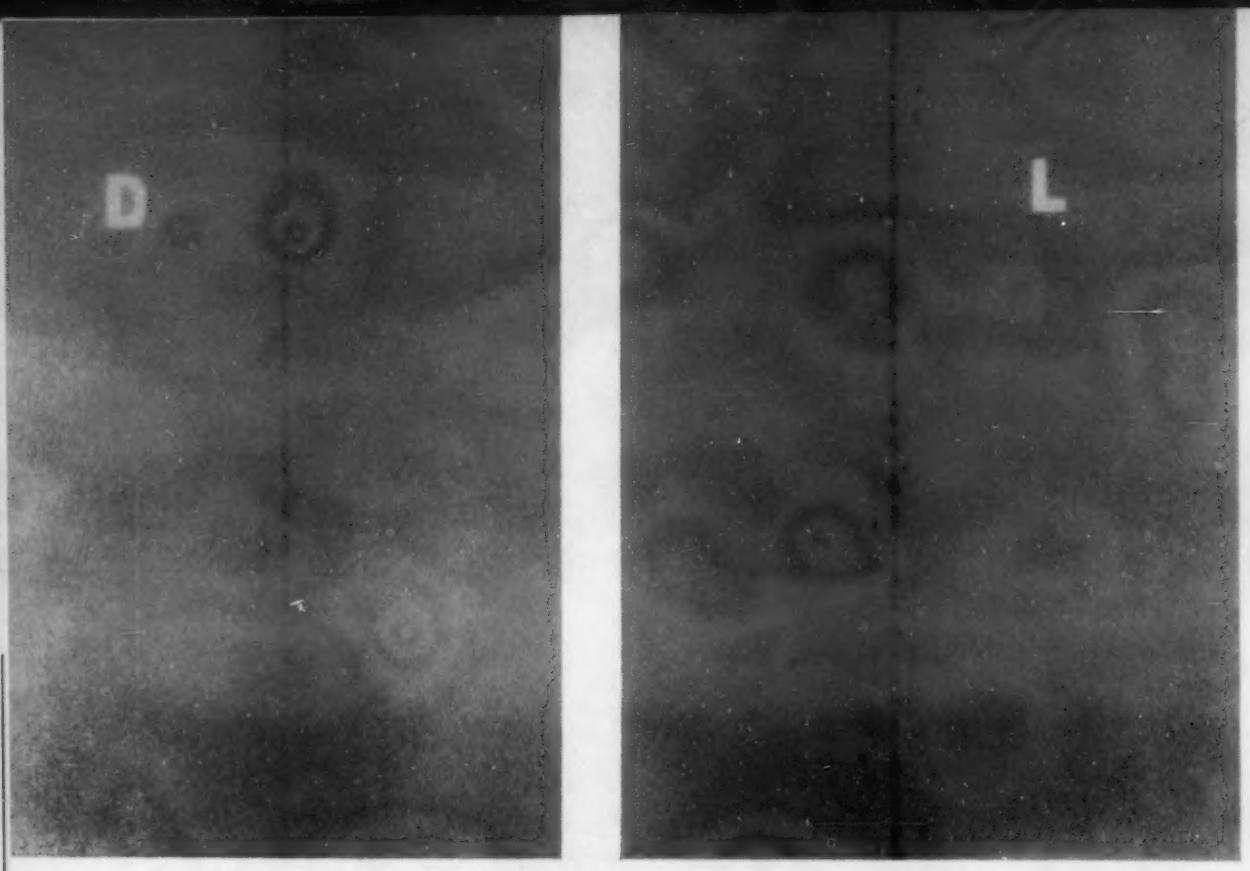


"D" is a direct exposure radiograph of an experimental weld in 2.1 cm. steel. Technique, 180 kilovolts peak, 8 milliampere-minutes, 1 meter target-film distance, Eastman No-Screen Film. "L" is the same weld, taken with the same technique except that lead screens were used and the exposure was reduced to 5 milliampere-minutes. The gain in contrast with the lead-screen technique is quite apparent.

surface of lead foil which is to be used as a screen may result in very poor radiographs. It is well known that different elements have different intensifying actions and, therefore, a coating of one on the surface of lead will not only interfere with the action of the lead but, if the second element is thin enough, it is apt to vary considerably in thickness, to the extent that a mottled appearance may occur in the radiograph. This is apparently caused by variation in electron absorption with thickness of the coating.

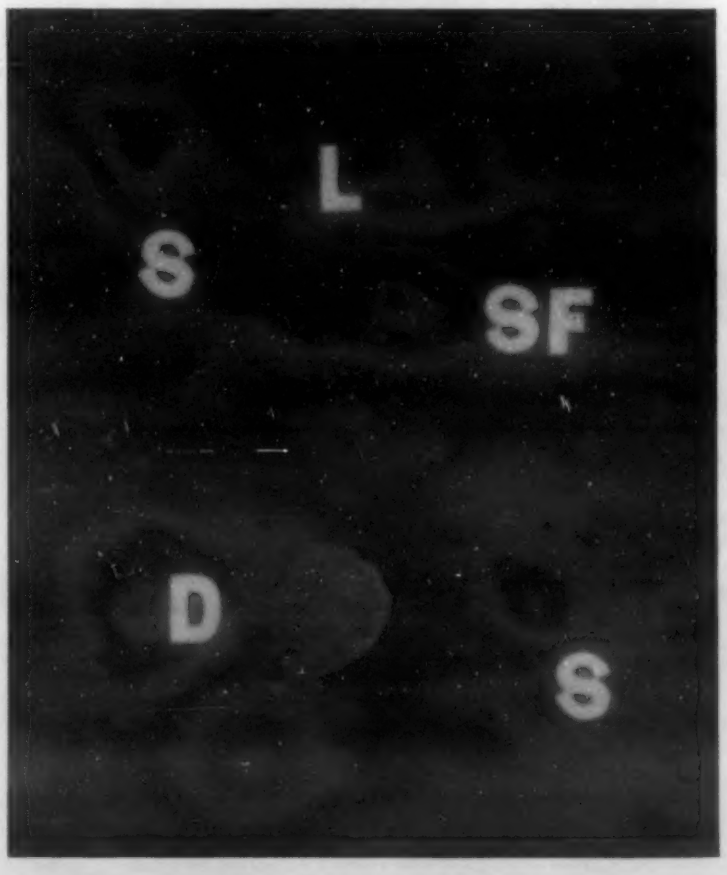
One type of artifact which may appear in a radiograph arises from desensitization of the photographic emulsion by excessive pressure. If a film holder is forced against an irregular surface, such as the bead of a weld, the pressure may be very high at a few points where there are sharp projections and thereby cause partial desensitization in these limited areas. The same type of artifact may occur from a wrinkle on lead foil. Such wrinkles can be avoided, however, by proper care in mounting the foil.

The marks on a lead screen from the use of a *fine* abrasive, such as fine steel wool, seem to have no detrimental effect on the radiographic image. It is interesting to note, however, that a deep scratch on either the front or the back screen will result in an increased density in the portion of the film covered by the scratch. Apparently this is due mainly to the provision of a short path of escape for the electrons emitted along the sides of the scratch. Severe scratches therefore should be avoided in using lead foil screens. Antimony-lead alloy foil of suitable quality for use as a radiographic screen might be referred to as "radiographic lead foil."

Fogging

Lead will cause fogging of film under certain conditions. For example, let a small area of a piece of lead foil be freshly cleaned with *fine* steel wool. Then place this in a cassette in contact with a film and leave it for a week or more. Upon development, the film may show a darkened area corresponding to the shape of the spot which was cleaned. Repetitions of this exposure yield a gradually decreasing effect so that it will eventually disappear. The same type of result may be observed with other metals and is probably caused by the reducing effect on the silver bromide emulsion of the fresh metal which is itself in the process of oxidation. This is not an argument against cleaning lead screens but indicates rather that they should not be cleaned unless suspected of being

The below artifacts on a back *lead screen were produced as follows: SS—a deep scratch, SF—steel filings, D—dried developer. The radiographic exposure was made through uniform 2.1 cm. steel in the usual manner.*



contaminated. The dingy appearance from normal use is probably due to a thin oxide layer which offers some protection against artifacts. Spots of grease, dirt, lint, and so forth, should not be allowed to accumulate. Bon Ami and water applied with a soft bristle brush are effective for ordinary cleaning. The Bon Ami should be *rinsed* off.

It is hoped that these methods of mounting lead foil for screens in the radiography of industrial materials will facilitate their use wherever they are applicable.

Direct exposure X-ray film, which is now on the market, is a very satisfactory medium to be used in connection with lead screens. The trade names for direct exposure film merely indicate that it is *not* designed for use with *fluorescent* intensifying screens. The regular screen X-ray film may also be used in conjunction with lead screens if a lower contrast is desired. It requires somewhat longer exposure than the direct X-ray film.

References

[1] Page, E. W., U. S. Patent no. 1,909,312.

[2] Seemann, H. E.: "Some Physical and Radiographic Properties of Metallic Intensifying Screens", *J. Applied Physics,* Vol. 8, Dec. 1937, page 836.

[3] Briggs, C. W. and Gezelius, R. A.: "A Study of Intensifying Screens for Gamma-Ray Radiography," *Proceedings of the 41st Annual Meeting A.S.T.M.,* Vol. 38, Part II, 1938, page 303.

Note on a Method of Surface-Working Small Metallic Specimens

by EDWIN M. SHERWOOD—*Battelle Memorial Institute*

IN THE COURSE of some electron diffraction investigations carried out at the Battelle Memorial Institute on the transformation of austenite in stainless steels, a number of experimental techniques for producing a worked surface layer on specimens were developed. One apparatus devised possessed sufficient novelty in design to be worthy of description.

Fig. 1 is a sketch of the work hardening apparatus. Compressed air is used to blow a number of small, steel balls continuously against the face of the specimen being treated. The air is forced into a fine jet by means of an internal nozzle so that as the balls fall back down into the well of the hardener they will be ejected again at high velocity. A number of minute holes were drilled in the side wall of the cast iron pipe (of which the specimen chamber is constructed) to permit escape of air. Ordinary pipe fittings such as cap, nipples, and elbows were used in the remainder of the apparatus. Each specimen is provided with a shallow, tapped 10-32 hole and is mounted on a 10-32 screw as shown in Fig. 1.

The nozzle itself was made from a drilled brass rod and was force-fitted into the pipe. The hole was of different diameters in its two parts. One of these sections was several thousandths of an inch smaller than the diameter of the steel balls used, while the other section was twice the diameter of the former.

The type of surface produced is shown in Fig. 2b at 20 diameters magnification. The initial surface (abraded through 4/0 paper) is shown in Fig. 2a, also at 20 diameters.

The thin surface layer is well worked and, for the proper alloy composition, the treatment can be shown to produce some transformation of the surface austenite into ferrite.

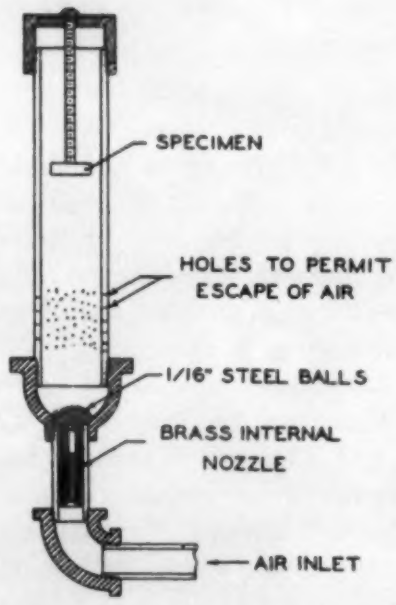


Fig. 1. Sketch of the apparatus.

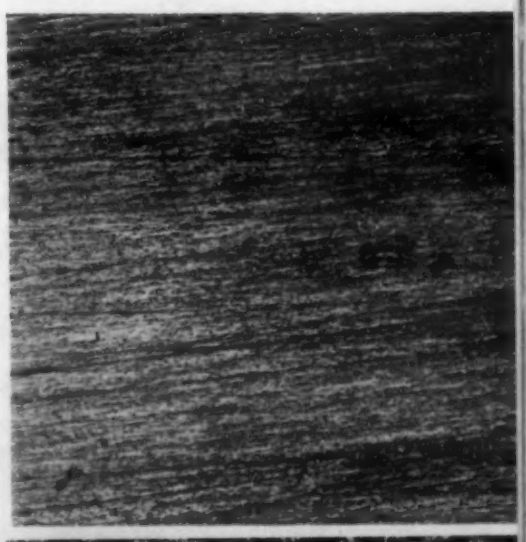


Fig. 2a. Surface prepared by abrasion through 4/0 paper. 20X.

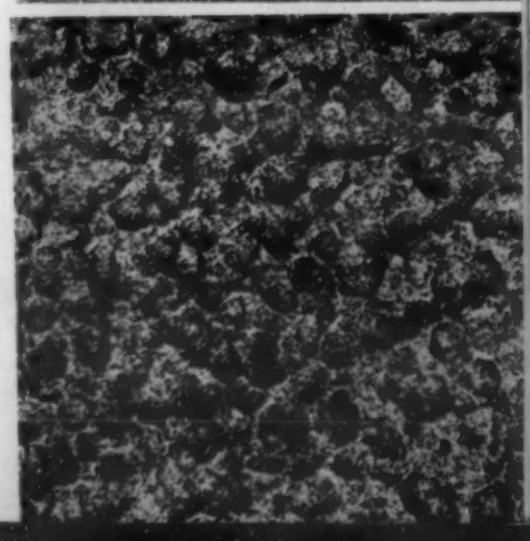


Fig. 2b. Abraded and worked surface. 20X.

Hydrogen, Flakes and Shatter Cracks

A Correlated Abstract - Part III

Part 2: Flakes in Steel

Early Observations on Flaking

Prior to 1914, the certain defect in steels known best today as "flaking" was quite unimportant among a miscellany of other defects. While its identity had been recorded in sundry writings, it remained for the accelerated production of nickel ordnance steels during the war period of 1914-1918—production by companies accustomed only to making plain steels—to focus attention on flaking and give the study of flaking its initial impetus.

Numerous publications appeared[22-49, 51-59, 61-66, 71-74, 76-86, 89-91, 93-96, 98, 99, 101-104, 106, 107, 110, 112, 117-120, 125-133, 136, 137, 142, 148, 151, 152, 155-157] that discussed flaking, but they left mostly confused conclusions. There one reads opinions placing the cause of flakes variously, as due to the refining operation, casting temperature, speed of casting, ingot size, uphill or downhill casting, quick heating in the rolling mill or excessive draft on rolling.

The mechanism of flaking was similarly disputed. Giolitti[32] and Sommer and Rapatz[63, 64] argued that areas of separated ferrite were responsible for flaking; whereas Hultgren[74] showed that flaking occurred in hypereutectoid steels where cementite, not ferrite, separated. Hultgren also showed that the flakes were oriented with the pressure diagonal of the last rolling operation; but Bardenheuer[71] contended that the orientation was with the ingot dendrites. Bardenheuer, examining the microstructures of flaked steel, found martensite lying next to pearlite. Presenting the curve shown in Fig. 10, he proposed that flaking was due to the difference in specific volumes of martensite and pearlite. He assumed that during solidification the oxide impurities and alloying elements diffused away from the primary dendrites,[68] forming a secondary structure high in foreign matter around the primary dendrites; and that these impurities lowered the transformation temperature of this secondary layer, permitting martensite and pearlite to occur together under conditions of rapid cooling.

Hayward[33] had obtained a curve showing the relation between the degree of flaking and the nickel content of steel, based upon 3000 observations. (See Fig. 11). Bardenheuer claimed that Hayward's curve substantiated the theory that flaking was due to the difference in volume of martensite and pearlite, and pointed out that more than three per cent nickel may prevent the formation of transformation products, whereas nickel up to three per cent lowers the transformation temperature and thereby favors coexistence of martensite and pearlite.

This transformation-stress theory was rather widely accepted. Maurer[83] and Eilender and Kiessler[107] attempted to show mathematically that, during the cooling of steel, the stresses resulting from differences in temperature, and consequently differences in volume, of contiguous internal parts might well exceed the tensile strength of steel. They argued that if the transformation temperature is lowered by rapid cooling, or by the presence of foreign elements, the volume change no longer takes place under plastic conditions, and the consequent internal stress then varies with the degree of undercooling.

Howard[26, 46, 55] found reason to believe that flaking was due to alternating tensile and compressive stresses that resulted from different cooling rates in rim and center; and that transverse fissures in rails were due to a similar alternation of stresses occasioned by the cold-working of the exterior when operating under over-load. On the other hand, Benedicks and Löfquist[96] concluded that local regions of poor cohesion gave rise to flakes; and Bronson[66] blamed localized brittleness. Giolitti[32, 127] blamed inclusions, but Waring and Hofamann[41] found no trace of foreign matter between crack faces.

Whiteley[90] aroused considerable speculation of a

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different sort when he found that flaky steel gave off large quantities of gas during etching. Because analysis showed an appreciable amount of carbon monoxide, Whiteley proposed that dissolved oxygen reacted with carbon during cooling to produce carbon monoxide, which could not diffuse out of the steel, and concluded that high pressures of this gas could develop in this manner.

Conditions Necessary to Flaking

Houdremont and Korschan[148] in 1935 clearly and rigorously defined for the first time the conditions under which flaking occurs. Realizing that much confusion had resulted from redundant terminology, these authors began by making the following distinction:

(1) *Flakes* first form after hot-working and are independent of grain boundaries (See Fig. 12);
(2) *Primary Grain Boundary Fissures*, though sometimes resembling flakes, are usually much larger, and appear in the grain boundaries of unworked cast pieces. They also occur in lightly-worked forgings as glazed, structureless, cracked surfaces, which by further working become almost fibrous. (See Fig. 13).

Regarding the effect of the steel making process, Houdremont and Korschan found, in general:

(1) That crucible and acid process steels show less tendency to flake than do basic process steels;
(2) That low casting temperatures, slow rates of casting and bottom pouring favor a diminution of flaking;
(3) That the form of the mold (cylindrical, 4-, 8-, or 12-sided) has no effect on flaking; and
(4) That mold coatings (lacquer, tar, etc.), other than graphite, increase the tendency to flake.

It had long been agreed that slow cooling after forging was essential for the prevention of flaking, but little work had been done to determine the exact temperature at which flakes form. Eilender and Kiessler[107] had proposed that the flakes formed at about 600 deg. C.,—near the transformation temperature. This conception was quite popular. Scheil[132] concluded that the formation occurred after the last stress reversal, which takes place at about 300 deg. C. in low nickel-chromium steels. The fissuring could not be detected by electro-acoustical methods. Giolitti[127] assumed that flaking occurred during testing.

Houdremont and Korschan thought that the appearance of the broken surfaces of flakes indicated formation at some time during the cooling period. Under the microscope, the grains showed no evidence of deformation. If the piece was annealed to produce grain refinement in the stressed area, the flake remained bright and unchanged in contrast to the surrounding fibrous surface.

To determine the temperature at which flaking occurred, these authors made tests using the following steels:

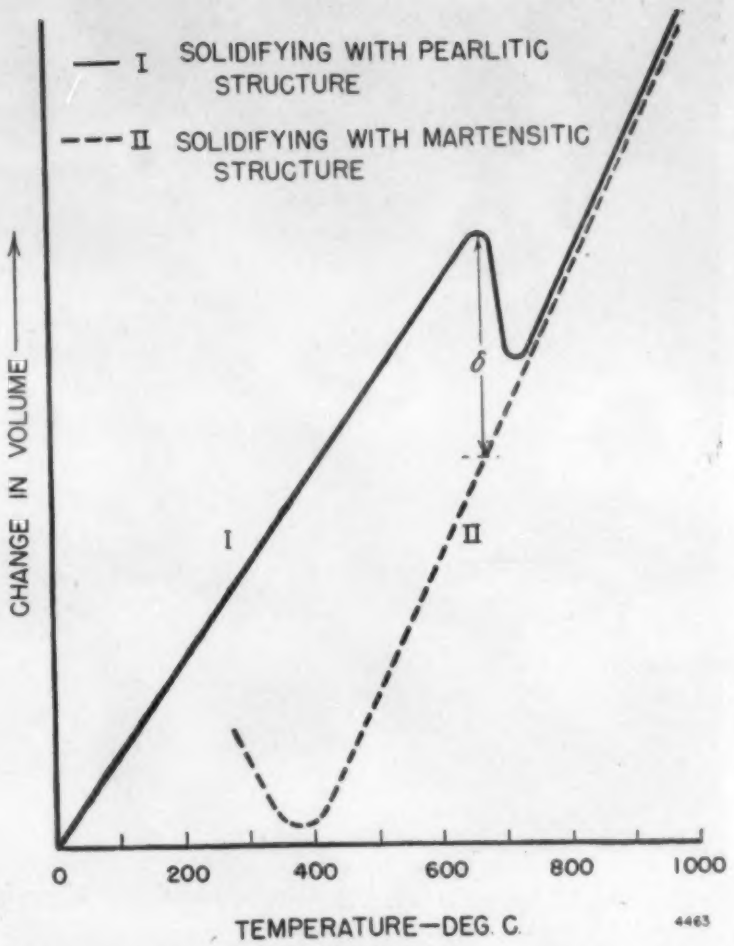


Fig. 10. Schematic representation of the volume change in a nickel-chromium steel. I: Pearlitic. II: Martensitic (Bardenheuer).

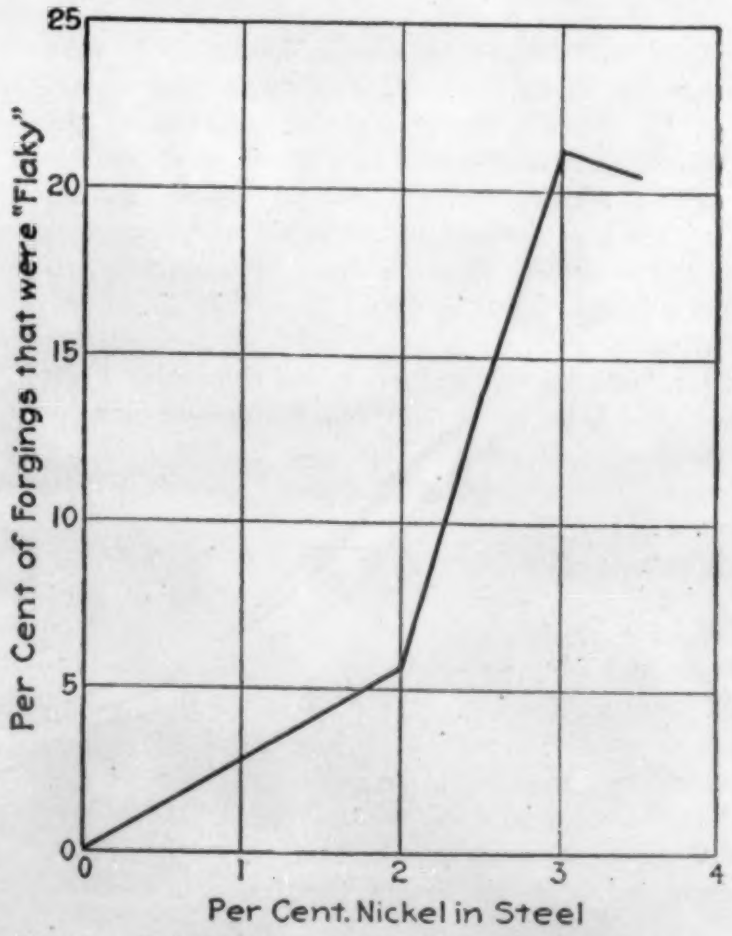


Fig. 11. Relation between nickel content and amount of flaking (Hayward).

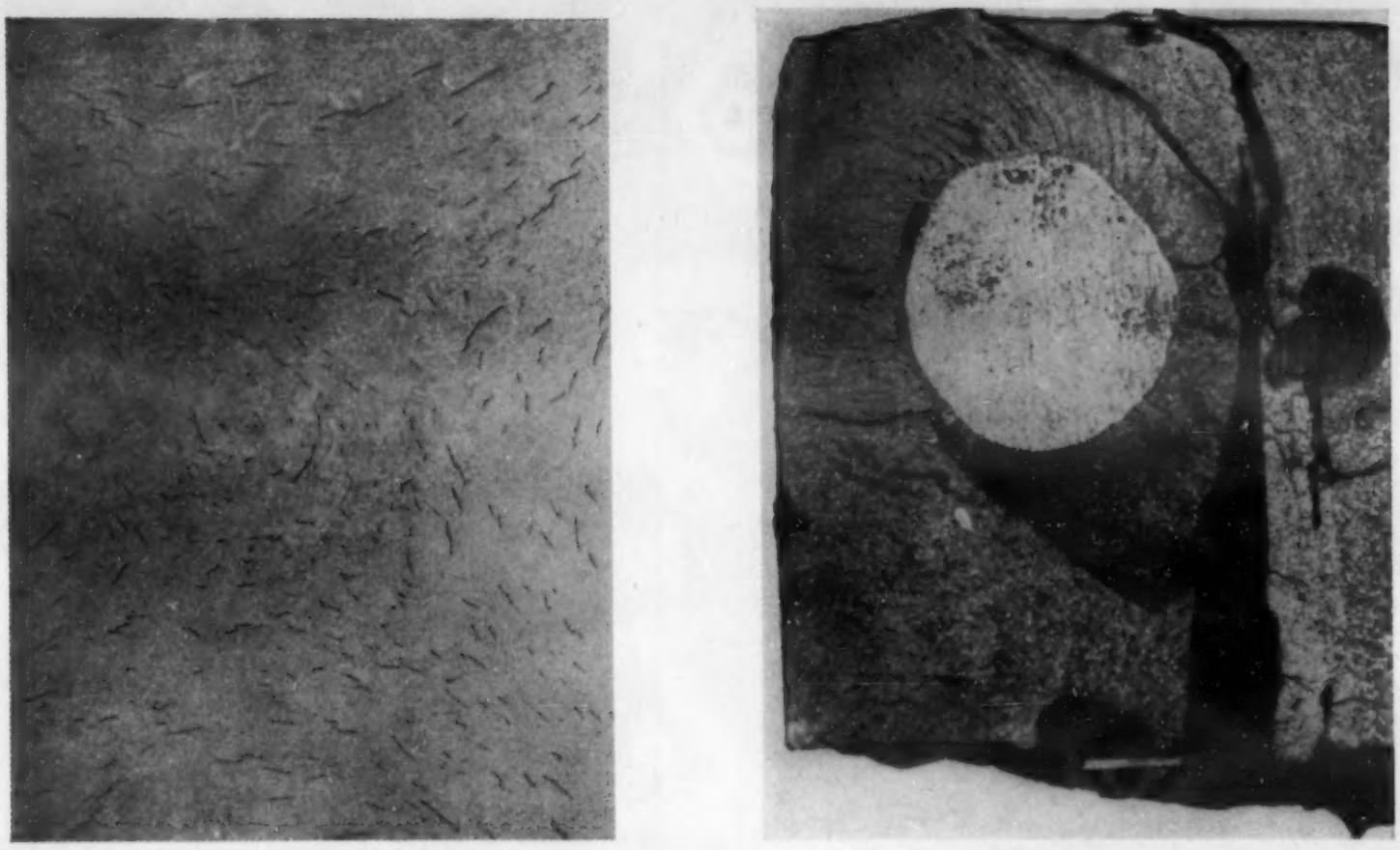


Fig. 12. Flakes in steel. (Houdremont and Korschan). Left: Etched surface. Right: Broken surface.

	C	*Si*	*Mn*	*Ni*	*Cr*
(1) Basic open-hearth	0.30	0.25	0.45	3.50	0.70
(2) Basic electric	0.45	0.25	0.65	3.50	0.50
(3) Basic open-hearth	1.0	0.25	0.35	0.10	1.4

Specimens forged to a reduction of 3½ were transferred directly after forging to an oven at 900 deg. C. After 1 hr. at 900 deg. C., one of the specimens was removed to cool in air. The furnace was then allowed to cool. At 700 deg. C. another specimen was removed to cool in air, and from then on at 100 deg. C. intervals down to room temperature a specimen was removed to cool in air.

All chromium steels air-cooled from temperatures above 300 deg. C. and all nickel-chromium steels air-cooled from above 200 deg. C. showed flaking. Others were flake-free. This was the first evidence that flaking occurred in the neighborhood of 200 deg. C.

These results were corroborated by evidence obtained under different conditions. Specimens of the same steel were forged equal amounts, but, unlike the first test, the pieces were cooled in air directly after forging. The progress of the cooling was followed by placing various alloys of known melting temperatures on the surface of the specimen. At temperature intervals of 100 deg. C., from 700 deg. down to room temperature, a specimen was interrupted in its air-cooling, transferred to an oven at 600 deg. C. and slowly cooled to room temperature.

All pieces placed in the oven before air-cooling to 200 deg. C. were flake-free. All others showed flaking.

This showed that the flaking occurred between 100 and 200 deg. C. Repetition of these tests half a year later reproduced every result. They concluded from this that slow-cooling through higher temperatures is not so important, but that it is specifically important to cool the specimen slowly through the critical range around 200 deg. C. It was noted that the amount of flaking in the specimen slow-cooled to 300 deg. was less than that in the specimen slow-cooled to 400 deg. C. This indicated that something also occurred between 300 and 400 deg. C.

In no test could Houdremont and Korschan obtain flake formation by reheating, forging and rapidly cooling a steel previously made flake-free by slow-cooling. Because no cooling stresses, transformation stresses, segregations or impurities could possibly appear during the first treatment that would alter the steel in a way to account for the absence of flakes in the second identical heat treatment, they concluded that none of the existing theories on flaking were adequate.

Some investigators had maintained that stresses produced during forging were responsible for flaking. To settle this point, Houdremont and Korschan forged specimens of the steels, listed previously, to a reduction of 3½ and transferred them directly to an oven at 900 deg. in one test and 1000 deg. C. in another. Specimens were left in the oven for 1, 2, and 3 hrs. to insure complete relief from forging

stresses, and were then cooled in air. Flaking occurred exactly as it had occurred when the specimens were cooled directly from forging, proving that stresses derived from forging are not responsible for flaking.

Conviction that transformation stresses, even in segregated steel, cannot account for flaking may be gained by considering the above data. The chromium steel, during air-cooling, transforms at about 680 deg. C., whereas the chromium-nickel steel transforms near 400 deg. C. In both cases the transformation temperature is considerably above the temperature at which flaking occurs; and in the series of tests wherein the specimens were oven-cooled to certain temperatures, including 400 deg. C., and below, both steels could have fully transformed before the air-cooling began and the flakes appeared. The theory of transformation stress as the cause of flaking may therefore be abandoned.

Houdremont and Korschan concluded that primary grain boundary fissures and flakes are ascribable to the same source, but that theories of internal stress, segregations and impurites are, in themselves, inadequate to explain either.

Flaking Attributed to Hydrogen

Bennek, Schenck and Müller,[141] in 1935 proposed that flaking was due to hydrogen in the steel. These investigators had had occasion over a period of years to observe about 9000 specimens from an induction furnace and 2000 specimens from an electric arc furnace, none of which had exhibited flaking. They then investigated the effect of hydrogen on a steel analyzing:

C	0.20–0.27
Si	0.15–0.30
Mn	0.45–0.60
Ni	3.40–3.80
Cr	0.60–0.90
P and S	low

100-lb. melts were made under a lime-fluorspar slag in a basic-lined induction furnace. Hydrogen was blown into the melt for 15 min. Aluminum was added in the ladle and the steel was poured into a water-cooled copper mold. The ingots were extracted shortly after solidifying, placed in an oven at 1080 deg. C. for 15 min., forged on two faces and air-cooled.

Sections from center and each end showed flaking in every specimen treated with hydrogen. Sand-castings were also flaky, but if a top was placed on the mold, only the top was flaky. Slow cooling reduced the flaking. Specimens forged on four faces showed conchoidal fractures with smooth faces.

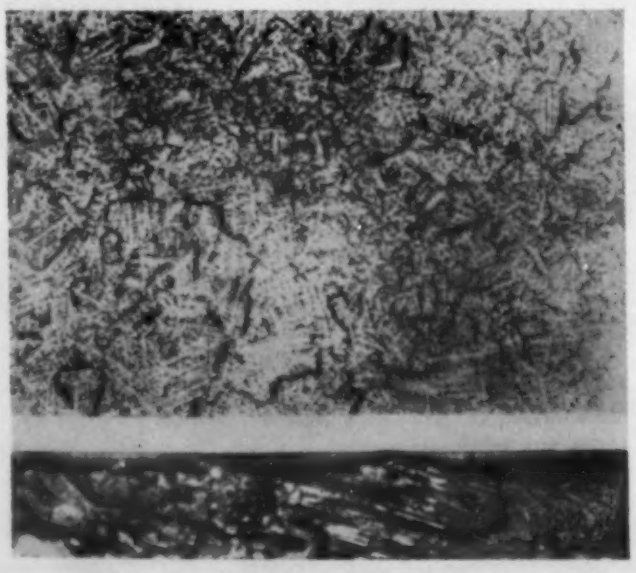
These authors added further disproof of the internal stress theory to that already provided by Houdremont and Korschan. Duplicate thermocouples were inserted in the rim and in the center of a flake-sensitive block in an attempt to find the temperature difference that exists between rim and center during air-cooling. No difference was found over the entire cooling range, and, as the accuracy of measurement was 10 deg. C., the temperature difference must be less than 10 deg. C.

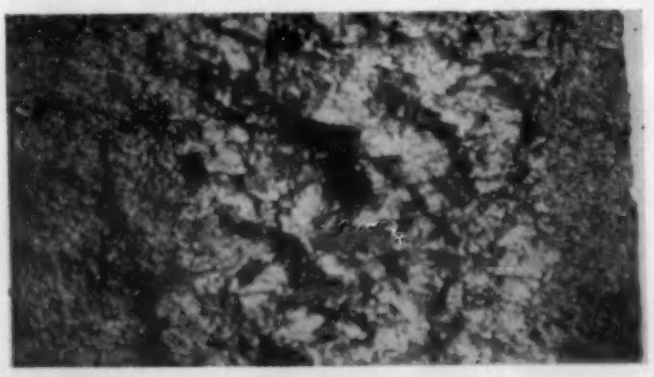
Tests showing the temperature at which flaking occurs, and the necessity for slow-cooling through this critical range, generally corroborated the results obtained by Houdremont and Korschan.[148] Evidence was presented to show that conchoidal fracture and intercrystalline fissuring are probably also functions of hydrogen. Addition of carbon dioxide to the melt did not produce flaking. Addition of ammonia did as would be expected from the dissociation of ammonia into hydrogen and nitrogen.

Bardenheuer, discussing the paper, stated that 10 yrs.' work at the Kaiser Wilhelm Institut für Eisenforschung had substantiated all the foregoing results.

Many investigations soon followed along this new line of thought. [143, 147, 153, 162-166, 169-173, 175-188, 193, 194, 197-199, 202, 203, 211, 216, 217, 220, 221, 224, 226, 228, 232, 237, 238]

Fig. 13. Primary grain boundary fissures (Houdremont and Korschan). Left: Cast structure; etched surface (above) and broken surface (below). Right: Lightly-worked structure above, broken surface below.





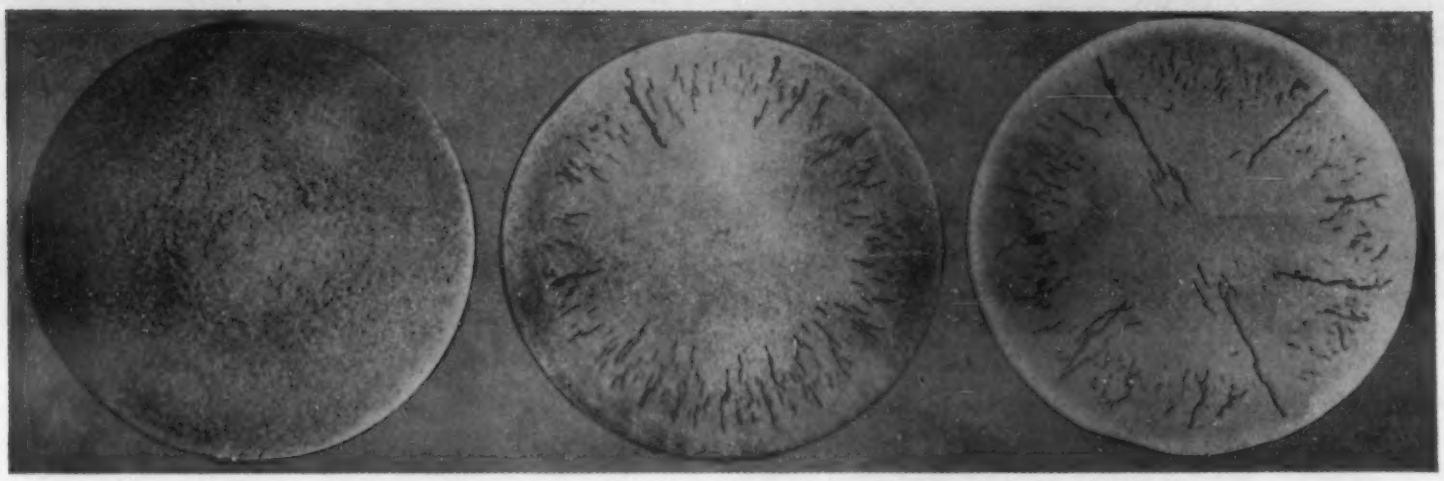


Fig. 14. Micrographs showing the various susceptibilities of high-grade steel to flake-formation after 7 hrs. in hydrogen at 1150 deg. C. Specimens water quenched (Musatti, Reggiori). Left: Carbon steel. Center: Ni-Cr steel. Right: Ni-Cr-Mo steel.

Musatti and Reggiori[153, 177-179] experimented with 6-in. blooms of nickel-chromium-molybdenum steel in the following manner:

(1) Immediately after rolling, two blooms were cooled in air to room temperature.
(2) Two blooms were cooled in air to 280 deg. C. (too high for any residual austenite in segregated zones to transform into martensite), were slowly reheated to 600 deg. C., held at this temperature for 2 hrs., so that all austenite could transform and temper, and then were cooled in air.
(3) The same as (2), except that the blooms were cooled in the furnace to 300 deg. C. before cooling in air.
(4) Blooms were slowly cooled in the furnace.

Only the blooms in (4), which had been cooled slowly to room temperature, were free from flakes. Thermocouples inserted in rim and center of these blooms showed a maximum difference in temperature of 20 deg. C. during cooling in air, which could not account for flaking. As the blooms were larger than those used by Bennek, Schenck and Müller, the data on temperature difference stand in agreement.

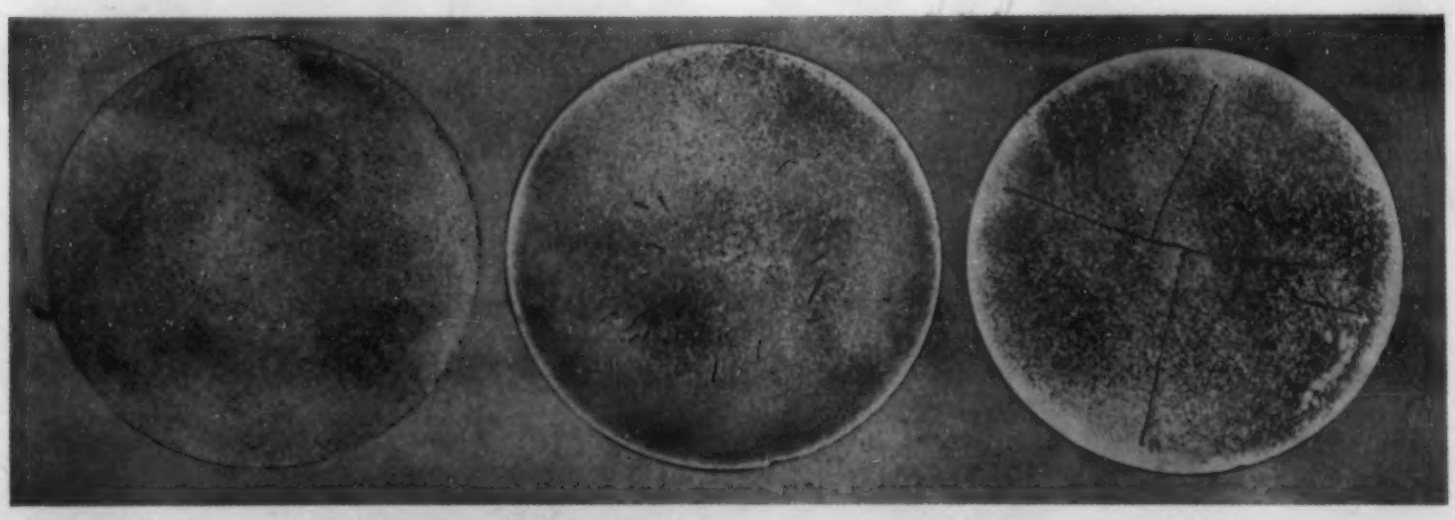
A 2-in. round bar of chromium-nickel-molybdenum steel was heated at 1150 deg. C. for 7 hrs. in a current of hydrogen and cooled in air. An end section showed no flaking. A second similar period in hydrogen still failed to produce flaking, but after a third period flakes appeared. Other tests showed flaking after the first 7-hr. period. Prolonged annealing in hydrogen merely increased the amount of the flakes. Heating in nitrogen did not produce flaking.

Three-inch cylinders of (A) high-grade carbon (0.40) steel, (B) (2.5) nickel-(0.85) chromium (0.30 carbon) steel, and (C) nickel-chromium-molybdenum steel were heated together in hydrogen.

Cross-sections of these cylinders are reproduced in Fig. 14.

In explanation of the fact that the flaking appeared in an intermediate zone within the cylinders, instead of at the center where trapping might be expected to be greatest, the authors pointed out: (1) That the

Fig. 15. Steels similar to those in the previous figure (Fig. 14) annealed at 1000 deg. C. for 5 hrs. in hydrogen. (Musatti, Reggiori).



cylinders had been loaded with hydrogen by diffusing the gas in from the surface; (2) That the diffusion of hydrogen from the rim into the atmosphere has provided the customary flake-free rim; (3) That the lower density of core metal acts against the development of high gas pressure in the core.

A similar treatment with cylinders in nitrogen produced neither flaking nor fissuring. A treatment in hydrogen at 1000 deg. C. for 5 hrs., followed by quenching in water, resulted as shown in Fig. 15. This treatment did not produce flaking in the carbon steel. Annealing in hydrogen for 30 hrs. at 800 deg. C., or for 150 hrs. at 400 deg. C., followed by quenching in water, produced no flaking in any of the steels. Annealing in hydrogen diluted with nitrogen showed flaking in a degree that varied with the fraction of hydrogen present.

Bardenheuer and Ploum[188] produced what they called flaking by electrolytically loading the steel with hydrogen. A flaked zone first appeared in the rim. With increased loading time the flaking zone deepened progressively toward the center. Fig. 16 shows this interesting progression.

Several specimens loaded equally with hydrogen were then broken after successive intervals of aging. The results of this test showed the flaking zone disappearing with increasing aging time. The sections are shown in Fig. 17.

Hydrogen dissolved in solidifying steel behaves like any other impurity. During cooling, pure metal solidifies first and insoluble hydrogen diffuses into inter-dendrite positions. If grain boundaries later collect the gas, intercrystalline fissuring may result; if the gas is trapped within the crystal, for instance at the disjunction of interfering dendrites, flaking may result.

Some interesting evidence of this segregating action has been presented by Esser, Eilender, and Bungeroth.[146] By soldering small chips from a flaked surface onto the target of an X-ray tube, a spectrographic analysis was obtained of the metal at the flake surface. In all cases a concentration of alloying element was found that far exceeded the analytical value for the steel. Furthermore, gas pressure was developed in the X-ray tube during the exposure of flaky steel, but not during the exposure of flake-free steel. On the other hand, Wrazej,[187] using chemical and microscopical analysis, did not find segregation of nickel or chromium at flake-surfaces.

Porosity reduces the tendency to flake or fissure because the volume of the gas necessary to build critical pressures is too great. If a porous casting is forged, however, occluded hydrogen will re-dissolve at the forging temperature in an amount dependent upon the solubility at that temperature, the pressure of the gas within the cavity and the forging pressure.

The mechanism whereby slow-cooling of flake-sensitive steel prevents the formation of flakes or shatter cracks can perhaps be most simply explained as functions of diffusibility and solubility already discussed. Infinitely slow cooling would permit equilibrium always to obtain, whereupon the pressure of molecular hydrogen trapped within the steel would never exceed the pressure of molecular hydrogen in the atmosphere. Slow cooling approaches this equilibrium as a limiting condition. The solubility of hydrogen decreases rapidly with temperature, but, if the rate of cooling is slow enough, hydrogen will not be forced into discontinuities more rapidly than the atomic portion in these discontinuities can re-dissolve and ultimately diffuse out of the specimen. In this way a large portion of the hydrogen may actually be removed from the steel, although it is quite likely that with ordinary rates of slow-cooling hydrogen is retained in considerable excess of equilibrium quantities. It is interesting to note that steels slow-cooled to 400 deg., and even 300 deg. C., still show flaking when subsequently cooled in air.

An insight to the origin of "flakes" and "shatter cracks"[238] has now been afforded. High pressures of gas contained in small discontinuities will exert an aerostatic stress on the metal surrounding the discontinuity. If this stress is great enough, the metal around the discontinuity will tear, but, once the tearing begins, the stress is immediately reduced by virtue of the increased volume of the discontinuity, the tearing stops and a small fissure remains. Subsequent fracture of the specimen, of course, will proceed across the faces of these internal fissures, exposing them. The exact mechanism by which such defects are formed will be carefully discussed in a later publication.

Although the pressure of the occluded gas may often be great enough in itself to fissure the steel locally, the failure of "spots"[238] and flakes to reappear after suitable annealing suggests that the aerostatic stress acts mainly as a complement to stresses applied externally, and that the resultant stress is responsible for the fissuring. It is certainly less reasonable to assume that the fissures weld together during subsequent treatment, or that fracture after annealing should refuse to avail itself of the shortest path—across tear faces.

Shatter Cracks and Other Defects Caused by Hydrogen

Heyn[15] and Wedding and Fischer[16] suggested many years ago that hydrogen gathering under pressure in solid steel must seriously affect its properties. Now, fissuring phenomena directly traceable to hydrogen in steel are too numerous to discuss completely.[158, 181, 191] To strengthen the argument that has been presented, however, several cases may be mentioned.

Bardenheuer and Ploum[123] loaded steel wire with

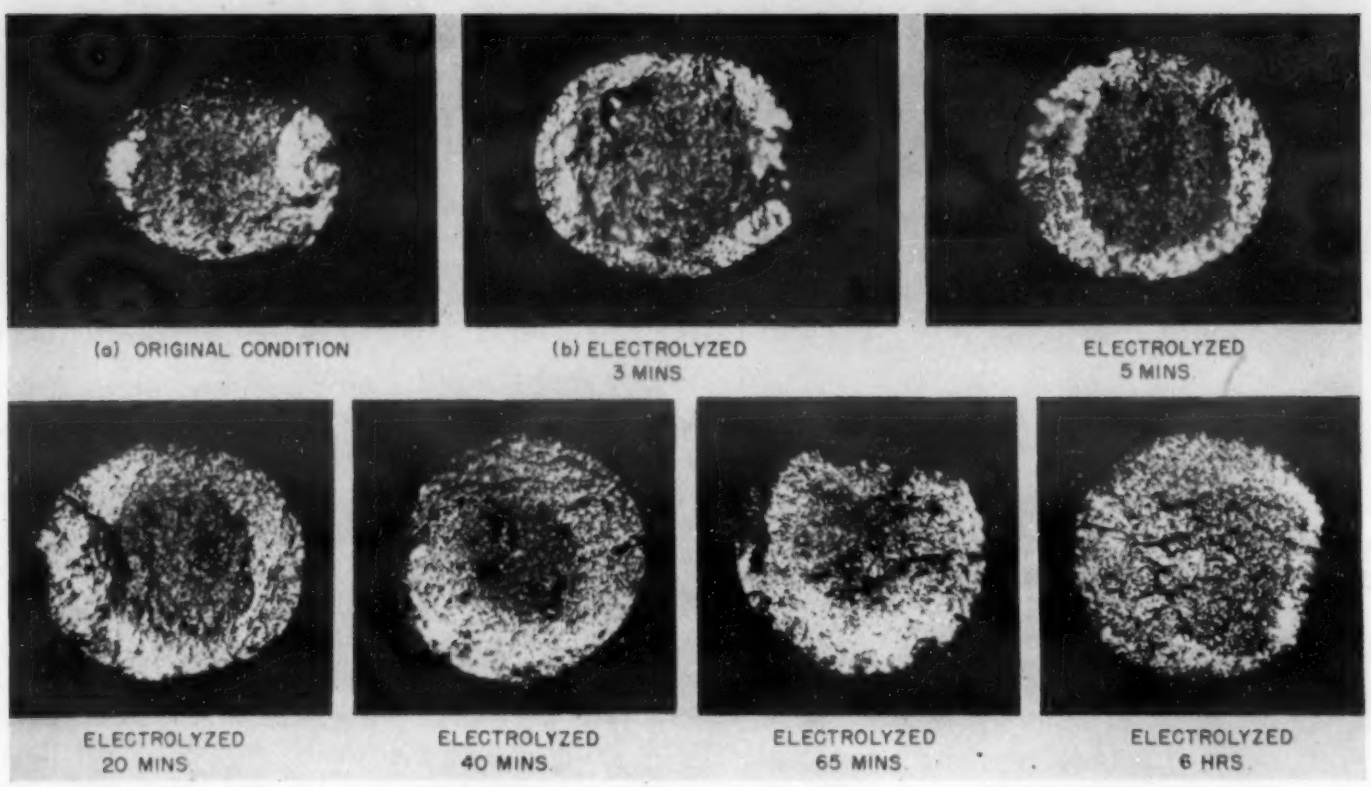


Fig. 16. Flaking in bar stock progressively loaded with hydrogen by electrolysis. (Bardenheuer and Ploum).

hydrogen, making the wire so brittle that bending nearly disintegrated it (See Fig. 18).

These same authors[124] showed that the hydrogen absorbed by steel during pickling previous to brazing expanded so rapidly during the brazing operation that fissuring resulted and the brass penetrated the steel through these fissures.

The attack of steel by hydrogen in ammonia synthesis is most severe and has been widely discussed.[69, 87, 88, 114, 121, 135, 139, 140, 150, 174, 204, 225] Apparently the embrittlement of boiler steels is likewise closely related to hydrogen.[154, 233]

Low carbon steel loaded with hydrogen is hot short between 1100 and 1200 deg. C. and red short from 800 to 900 deg. C.[158] If enough hydrogen is added, the steel cannot be forged without breaking. The deep-drawing properties of steel are greatly impaired by hydrogen.[211] The torsion strength is decreased,[123] and the elongation and reduction of area is reduced.[165]

A great deal of attention has recently been paid the defects caused by hydrogen absorbed during welding operations,[210, 229, 231, 239] especially when atomic hydrogen is used. Bardenheuer and Bottenberg[210] measured the quantities of hydrogen present near the weld and away from the weld both before and after welding. Conclusive evidence of hydrogen pickup during welding was found and a very reasonable theory was presented to explain the fissuring that often makes welds defective.

In the Third Progress Report of the Joint Investigation of Fissures in Railroad Rails,[202] Moore states that every rail treated with hydrogen developed shatter cracks. In the Fifth Report[234, 237] these results are corroborated, and a photomicrograph of shatter cracks shows a striking resemblance to the flaking fissures shown in Fig. 12 of this review. Moore also states in the Fifth Report that when the crust of a hydrogen-treated ingot was burned open with an oxygen flame, a ½-in. stream of molten steel shot 5 ft. into the air for half a minute due to the pressure of the gas.

Gathmann,[195] discussing transverse fissuring in ingots, presents observations that might be explained as functions of hydrogen. Remarking that the fissuring occurs like an explosion, Gathmann explains the fissuring as a result of ". . . heating the outer surface of the ingot so rapidly that it expands considerably before the inner portion has become sufficiently hot to expand with it, and the cooler portion is stressed to its breaking point." It is noteworthy that steel in the ingot stage likely contains more hydrogen than in any later stage and that the size of an ingot must largely defeat escape of the gas. The fact that the fissuring occurs like an explosion, and that the stresses apparently operate in the cold, central part of the steel instead of spending themselves in the more plastic rim, strongly indicates gas activity.

Many similar contributions purposely or inadvertently strengthen the belief that hydrogen is the cause of flaking, and also shatter cracks. It must be understood, of course, that stress from other sources may aid greatly. In many instances stresses from other sources may provide the critical increment of force without which fissuring would not occur. The hydrogen theory only states that no stress except that developed by hydrogen is sufficient in itself to pro-

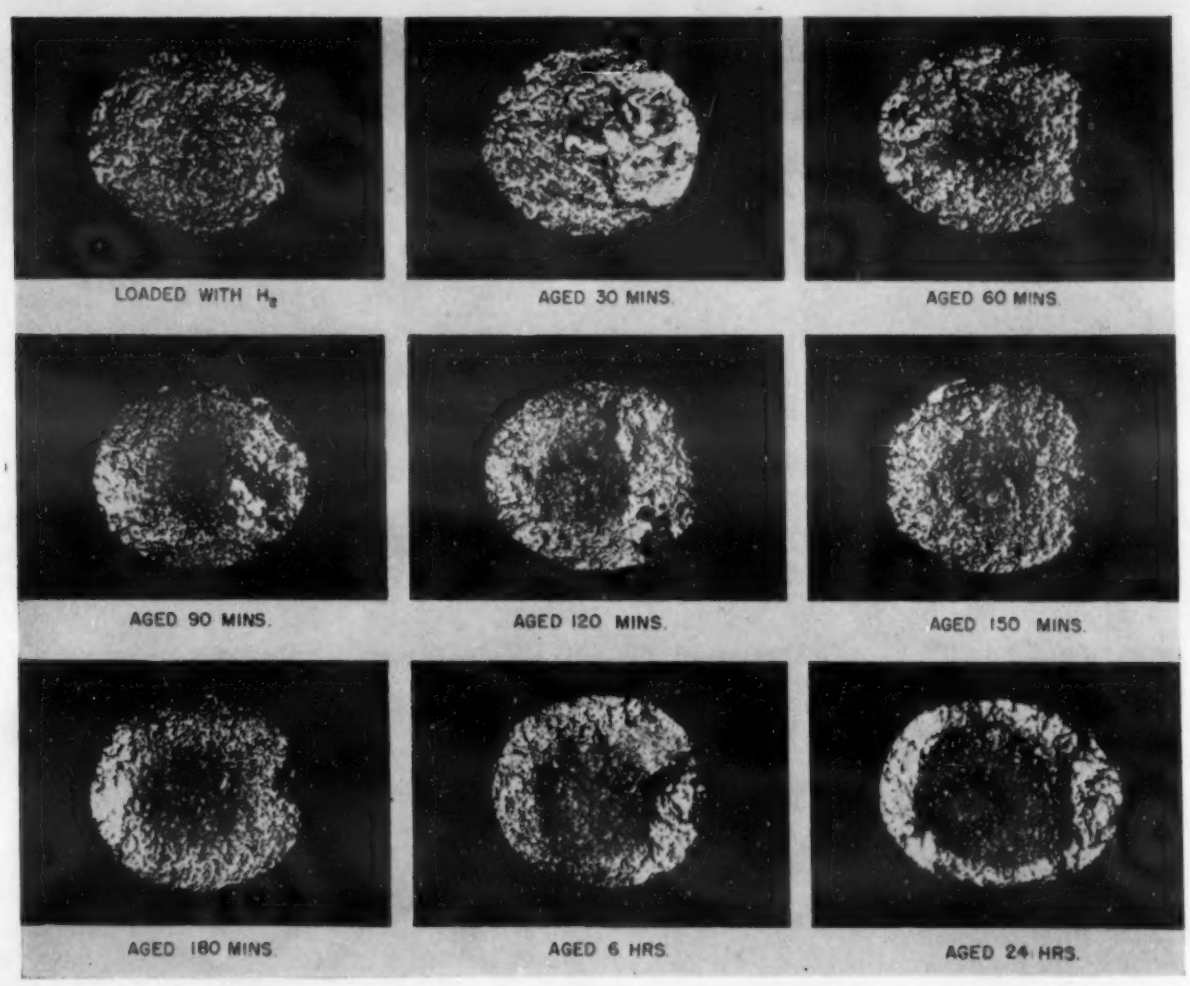


Fig. 17. Disappearance of flaking with aging in round bar stock loaded with hydrogen by 10 min. electrolysis.

duce flaking.

Klausting[198, 199, 217, 220, 221, 224] still feels that neither hydrogen nor stress theories are sufficient in themselves to explain flaking. He shows that a relation exists between flaking and transformation in steel; that flaking does not occur during the transformation, but after an incubation period that he attributes to the slow diffusion of hydrogen. Klausting's observation is all right, but his conclusion seems unnecessarily restricted. To those who have followed the discussion so far it should be clear why flakes are sometimes found oriented with rolling stresses or sometimes with dendrites; occurring during or after transformations in the steel, or during testing; and variously associated or not associated with inclusions.

First, aerostatically stressed by the accumulating gas, these rupturing areas should be expected often to orient themselves with externally applied stresses, as an aerostatic stress operates equally in all directions, and rupture will lie in the direction of the resultant of all stresses.

Secondly, rupture should be expected to appear at a time and at a temperature when all stresses in the particular steel under consideration combine to exceed the strength of that steel. Because the strong, general effects of changes in solubility and diffusibility are quite common to all steels, the temperature range in which flaking occurs is necessarily restricted.

Thirdly, transformations during cooling are mainly related to fissuring because they are accompanied by great decreases in hydrogen solubility. If the aerostatic stress at the time of the transformation is not great enough to cause rupture, or if the steel is too plastic to support stress, rupture should not be expected until lower temperatures are reached where the attendant decrease in solubility permits that stress to develop. If the aerostatic stress is still insufficient to cause rupture, flakes may appear during testing, as observed by Giolitti,[127] when the sum of the aerostatic and applied stresses exceeds the strength of the steel.

Lastly, rupturing should be related to inclusions by the phenomenon of occlusion and by the fact that dirty steel often predicates gaseous steel.

Evidence pointing to hydrogen as the cause of flaking in steel, and numerous similar defects, is so abundant, and so conclusive, that it is now more important to investigate means of eliminating hydrogen from steel than to review further evidence.

(*To be concluded*)

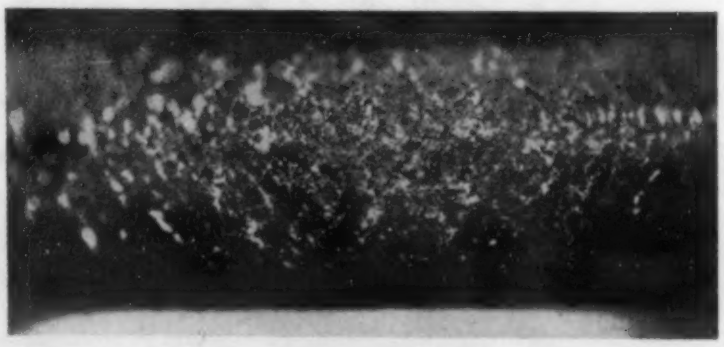


Fig. 18. A 3/16-in. wire loaded with hydrogen and subsequently bent. (Bardenheuer and Ploum).

(Editorials continued from page 19)

Western Metal Industry?

Will there be pronounced activity in the metal industry in the northwestern part of the country as a result of the building of the Bonneville Dam? Several developments recently point to the use on a large industrial scale of the electricity soon available.

The most recent indication is the announcement of a contract for power by the Sierra Iron Co., which will operate an iron ore reduction plant at Vancouver, Wash., to produce ultimately up to 500 tons of pig iron per day.

Another development is the authorized plan of the Aluminum Co. of America to build a new plant to produce some 30,000,000 pounds of metal yearly at the same location using power from the same place.

The Mining Experiment Station of the State College of Washington is actively emphasizing the electrolytic production of magnesium from magnesium-bearing ores, said to be plentiful in that territory. The statement is made that "the biggest boom among the metals in the next five years can be expected to occur in magnesium." Today the metal is extremely scarce, all production being sold for some time to come.

We have heard other rumors of possible developments in steel, metals and alloys, based on the use of what is reported to be exceedingly cheap electricity.

There is, of course, a lot of wishful thinking in the official publications on opportunities for metallurgical industries using Bonneville power. Unless power is a very important factor in costs, which is true of aluminum, the economics seldom figure out favorably, since transportation costs tend to throw the balance against the possibility of black ink.

A situation like this can create a field day for stock jobbing schemes, and the roseate tinge given the picture by official publications is nice for the promoter.

There will doubtless be cases, like that of aluminum, where the economics add up in the proper column, but many of the discussions of potentialities are obviously tinged with propaganda.

It will be interesting to watch actual developments, which, if sane and slow, will be worthwhile. —E. F. C. - H. W. G.

A First Line of Defense

At the recent celebration of its 15th anniversary by the Chrysler Corp., F. M. Zeder, vice chairman of the board and senior member of the company's engineering group, in addressing those present at the opening of two new engineering buildings said:

"May these laboratories and those of General Motors, Ford, General Electric, Westinghouse, American Telephone and Telegraph, and other large centers of industry serve as our first line of defense."

Research, both in metallurgical engineering and in other engineering fields, is of first importance in our industrial progress and in our adequate defense.—E. F. C.

letters
TO THE EDITOR

Pinhole Corrosion in Galvanized Watering Tanks

To the Editor: The report by Messrs. Peirce and Bartells (METALS AND ALLOYS, Vol. 11, February 1940, page 42) is very interesting because we know of nothing which has been published previously to explain shothole corrosion in galvanized watering tanks. In summary, they find that 14 samples, whose average life was 25+ yrs. had tin contents of 0.02 to 0.28 per cent. Thirteen samples whose average life was only 1.3 yrs. had 0.31 to 1.4 per cent Sn.

In view of the closeness of tin contents in good and in bad tanks (0.28-0.31%) and because this type of pitting is ascribed to electrolytic action between tin and zinc, it would have seemed desirable to take more bad samples which have lasted years in between 3 yrs. (the maximum for the bad ones) and 13 (the minimum for the good tanks) (.05% Sn). From the data presented by Messrs. Peirce and Bartells it would appear to us that there are other factors which contribute to shothole corrosion.

The senior writer of this letter has observed in a number of watering tanks, which showed the above type of corrosion, the presence of cementite near the surface of the galvanized low carbon steel. Wallace and Rickett (A.S.M.

Preprint 15, October 1939) show cementite coming down on annealing very low carbon rimmed steel. Bablik and coworkers. (*Z. Metallkunde*, Vol. 31, Aug. 1939, p. 287; METALS AND ALLOYS, Vol. 10, Dec. 1939, p. MA 723L/1) cite bibliography on similar effects. They show that cementite crystals at the surface directly under the rolling scale is the cause of an uneven thickness of zinc coatings, and also, that cementite-rich steel portions are more soluble in molten zinc. They found that over cementite the alloy layers were heavier.

Although, electrolytically, tin accelerates the corrosion of both zinc and iron; carbon, and for that matter carbide, distributed in the alloy layer may be expected to corrode zinc and alloy layers much more rapidly than tin.

Other factors should also be taken into consideration such as sand, organic materials, and others on the bottom of the tanks. It is also surprising that of so many tanks made (J. Amer. Zinc. Inst., Vol. 20, 1939, p. 128) only relatively few fail rapidly.

More research appears to be necessary to establish all the causes for shothole corrosion.

W. E. Buck, Sheet Metallurgist
F. R. Morral, Research Metallurgist
Continental Steel Corp.
Kokomo, Ind.

P.S.: It is of interest to remember what Dr. Evans wrote some years ago (*J. Soc. Chem. Ind., Trans.* Vol. 45, 1926, p. 37) on how to initiate corrosion at a chosen point on commercial sheet zinc and other materials:

1. Contact with some foreign particle.
2. Local removal of a protective film by abrasion.
3. The wetting of the point with a drop of liquid before the rest of the surface is immersed.
4. The production of a tiny cranny at the point of question.

More recently this same scientist, who has contributed so much to the understanding of corrosion (R. S. Thornhill and U. R. Evans, *J. Chem. Soc.*, 1938, part II, p. 2109), has made electrical measurements suggesting that corrosion is wholly electrochemical.

The last report of the A.S.T.M. (*Proc.* Vol. 39, p. 247) indicates that the electrolytic corrosion of zinc is favored mostly by iron, next by lead, and finally by tin for the stations studied.

In addition, one of the writers has found by electron diffraction analysis that the galvanized sheets as they emerge from the galvanizing operation have a thin protective layer of zinc oxide (7th meeting of the Galvanizers Committee, Pittsburgh, April 1940).

All these various factors expressed in the technical literature are not considered in the above study of the shothole corrosion of galvanized watering tanks.

Comment by the Authors

To the Editor: We have read with interest the comments by Messrs. Buck and Morral on the article which appeared in the February issue of METALS AND ALLOYS, dealing with the general corrosion of galvanized stock watering tanks.

There is one point which we should like to clarify. Messrs. Buck and Morral imply that, in selecting the bad samples, we have taken only those with a short service life. This is not the case. Bad samples were taken wherever available, regardless of the age. The fact that the bad samples were of such short service life is, in our opinion, simply an indication that, where this type of failure is found, it occurs quite rapidly.

Secondly, we would like to point out that the collecting of samples and their analyses for tin has continued and at the present time, we have examined 37 specimens of which 17 have shown good service—all but one running below 0.24 per cent Sn—and 20 have had very short life and most of them were pinholed. All ran above 0.54 per cent Sn, with one exception. One sample having 30 yrs. of service, analyzed 0.37 per cent Sn but, due to the practically complete removal of the coating, this analysis may be in error. One sample, pinholed after 11 mos. of service, analyzed 0.31 per cent Sn.

Third, we wish to state that, in the original investigation, the greatest attention was given to the possibility of these pinholes originating from the presence of foreign materials. Fortunately, there were cases where rather clear indications could be obtained that the presence of foreign materials had not occasioned the corrosion, and other cases where corrosion had not occurred in the presence of foreign materials.

Finally, we would like to emphasize that the purpose of our paper was not to claim that the tin content of a galvanized coating was the sole factor in determining whether or not pinhole corrosion occurred under conditions of total immersion. If tin content is not one of the most important factors—if not *the* most important factor—then it seems to us nothing short of miraculous that there should be a perfect correlation between tin content and the presence or absence of pinhole corrosion among 37 samples which had been taken as they came, every available sample being examined.

We have no statistics as to the percentage of watering tanks which fail but we do know that the percentage is high enough to have caused the complaint which brought the matter to the attention of the American Zinc Institute, and it would appear to us that further work such as Messrs. Buck and Morral suggest would be in order but that it would also be in order to take advantage of the remedy which has been indicated by the present investigation.

W. M. PEIRCE
Chief, Research Division

More About "Wanted—Words"

To the Editor: The editorial in the June issue of METALS AND ALLOYS entitled, "Wanted-Words" aroused in me a sympathetic response. Especially do we need clearer nomenclature for the limiting stress which causes structural damage to metals by permanent distortion. "Elastic Limit," "Proportional Limit" and "Yield Point" are all defined in rigid terms and, as the editorial "Wanted-Words", pointed out, fail to meet the need of a name for such a usable index of elastic strength for most materials.

The American Society for Testing Materials has introduced the term "yield strength" as a general name, but to be most useful the term should be modified by a numerical factor. The numerical value of deviation from Hooke's Law which causes appreciable structural damage differs for each material and for each use. It can be expressed numerically in per cent as an "offset" from the straight-line portion of the stress-strain diagram and we could speak of the "0.2 per cent offset yield strength" (or of the 0.1 per cent or 0.02 or of any value which was judged to represent the beginning of appreciable structural damage). This is a clumsy phrase to use, but remembering how "pounds per square inch" has become abbreviated to "psi" we might hope that "0.2 per cent offset yield strength" would become abbreviated to "0.2 oys."

H. F. MOORE
University of Illinois, Urbana, Ill.

Electron Diffraction Study on Hot Galvanized Sheets

To the Editor: In sheet galvanizing practice, fumes from burning sulphur are blown on the coated sheets soon after they leave the exit rolls of the galvanizing pot, and before the molten zinc coating has completely spangled and solidified. The principal reasons which the galvanizer advances for using these fumes is to improve the brightness of the coating and to prevent staining. If no SO_2 fumes are used, the sheets appear yellow. If too large a volume of the sulphur fumes are used, the coating forms small bright spangles. The galvanizer controls the amount of these fumes to obtain an even blend of bright and dull spangles.

An electron diffraction study was made on galvanized sheets. The patterns obtained from bright and dull spangles from freshly galvanized commercial sheets showed the presence of a relatively heavy randomly oriented, zinc oxide film.

The electron diffraction patterns of samples of galvanized sheets on which an excess of the sulphur fumes had been blown again showed only ZnO. But this time, some of the ZnO was definitely oriented with the basal plane (001) parallel to the surface. In two of the three samples used the degree of orientation seemed to be about $\pm$ 30°. On the third, the general appearance was the same but in addition, rather strong (002) (004) and (006) spots indicated that a small percentage of the crystals were quite closely oriented in the same manner. No traces of sulphides, sulphates, etc. could be detected in the photograms.

Similar highly preferred oriented ZnO film on zinc[1] has been found by immersing zinc in water for two hours. The same specimen immersed two hours more gave a randomly oriented zinc oxide film.

That a zinc oxide film forms on a galvanized sheet on leaving the hot galvanizing pot (800 deg. F. and more) should be expected in view of the affinity of zinc for oxygen at high temperatures.[2] From these observations it is apparent that in addition to controlling the spangling of the sheets, the SO_2 fumes determine the amount of oxide found on the freshly coated sheet.

Without SO_2 fumes a heavy yellowish layer of oxide forms on the coating; with an excess, the layer is thin and highly oriented by the proximity of the underlying zinc; and with normal amounts of SO_2 fumes, the layer is thick enough to lose the orientation at the surface, yet thin enough to be transformed.

[1] R. A. Anderson and M. L. Fuller, Metals and Alloys, Vol. 10, 1939, page 282.
[2] W. H. J. Vernon et al, *J. Inst. Metals,* 1939, page 65. Adv. copy No. 838.

Apr. 23, 1940

F. R. Morral
Research Metallurgist
Continental Steel Corp., Kokomo, Ind.
H. J. Yearian
Physics Department
Purdue University, Lafayette, Ind.

Uranium and Its Isotrope, U 235

There has been frequent discussion in the newspapers lately concerning the metal uranium and some rather extravagant claims have been made. Bearing on this subject we have received the following "Letter to the Editor":

To the Editor: Uranium metal and its isotrope U 235 have been frequently discussed in the public press in the last few weeks. My work on uranium ores has convinced me that U 235 is only a laboratory novelty. It is the custom of newspaper reporters to treat a subject in a sensational way so as to make it attractive to their readers. I feel that this has been the case as to uranium.

There are numerous isotropes of the elements 93-94-95 and 96, all of which are radioactive and a majority of which are present in uranium ores. The subject of the processes of recovery involved is a very complex one, and all of the recent newspaper publicity has caused, in my opinion, a type of hysteria affecting persons who know very little of the chemistry involved. This has created a fictitious value for uranium so that some persons, holding very pure uranium deposits which it would not pay to treat for extraction, might profit thereby.

Uranium oxide has been supplied to this country by Belgian interests in a small way but in a larger way by Eldorado Radium of Canada which extracts uranium from a high-grade ore not obtainable in the United States. Competition in this market is visible on the horizon due to the discovery of the Bingo claims, a new, very rich source at Hottah Lake, Northwest Territory, Canada.

Uranium metal has not been used extensively in this country in the pure form. It has a strong affinity for oxygen and therefore cannot be heated in air without burning up. I have sent some of the pure metal abroad in the form of ribbon and ingots which was used for experimental purposes and to make certain alloys. This metal was 99.99+ per cent pure. A metal of 99.94 per cent is considered very impure and is so brittle that it cannot be fabricated or rolled, whereas the pure metal is very ductile.

For the past few years I have made a survey of uranium deposits and would be glad to hear from anyone who has a deposit of uranium ore. A small sample of a few ounces sent to me will be checked for the uranium oxide (U_3O_8) content and a report mailed to the sender without charge.

The total consumption in the United States of uranium oxide is 300,000 lbs. per year.

Wallace M. Minto
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METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

Alloys
Applications
Designs
People
Plants
Societies

National Defense

The metallurgical engineer must expect to play a dominant role in this country's already-begun defense-preparedness effort. One big difference between twenty-five years ago and today is in the present-day large number of such engineers—men that are specialists in making and processing metals and metal products—and metallurgical engineering control of many of the operations involved in supplying this country's military needs is a modern common-place that has already lifted these operations to a quality and quantity level undreamed of 25 years ago. Here are some recently reported developments related to the preparedness program.

Raw Materials

With respect to developing significantly useful domestic sources of strategic materials—manganese, tin, chromium, tungsten, mercury, nickel and antimony—the Bureau of Mines reports that the situation is "promising" for all except nickel and tin. At the same time, metallurgical engineers continue their attempts to develop worth-while replacement materials for those that might be shut off from us in time of war.

Tungsten high speed steels have for many years been practically interchangeable with molybdenum steels containing much less tungsten. Alloys to replace tin-base bearing metals and container metals other than tin-plate are already available, although involving compromises of one kind or another. Sulphide-formers other than manganese are being evaluated for steel making, and so on.

Airplanes and Mass Production

The increasing volume of stainless steel wire used in aircraft manufacturing is one of the moving factors behind Allegheny Ludlum Steel Corp.'s construction of a new building for its Dunkirk stainless steel wire mill that will just about double its capacity. Wire as fine as 0.003 in. diameter, to be used for woven-strand airplane control cable and other purposes, will be among the products of this modernized mill.

And speaking of airplanes for defense, Chas. F. Kettering, vice-president in charge of research, General Motors Corp., recently pointed out the importance of the *time* required for design and tooling in any mass-production effort. Addressing a group of editors of trade and technical papers invited by General Motors Corp. to a luncheon and preview of progress in research on June 17th at the company's New York World's Fair exhibit, Mr. Kettering said that reports of producing 1,000 planes a day might tend to create a false impression. The average American does not realize how long it takes to get ready to produce machines on a mass-production basis.

Pointing out that in the automobile industry it takes more than a year to prepare a new model for production, and that the more complex the machine the longer the preparation-time required, Mr. Kettering said that the first mass-production industry in the world was the printing industry. "All we do is to publish autos instead of books," he declared. He warned that it was as impossible to change the design of a machine, once a mass-production program had been begun, as it was to change a word in a newspaper after the presses were all ready to run.

"Tooling with men and machines for national defense" will be the keynote of the semi-annual convention of the American Society of Tool Engineers in Cincinnati, Ohio, Oct. 17th to 19th. Symposia on education by industry of the designers and tool engineers required, on aeronautical preparedness and on gear production methods are to be held.

Heat Treating Facilities Expand

Typical of new metal-processing equipment that will help in meeting the requirements of the American preparedness program is a fully mechanical furnace for mass production heat treatment of forgings, castings, or rough-machined parts of uniform size, under closely controlled temperature and time conditions, recently installed by Metlab Co., commercial heat treaters of Philadelphia.

This furnace has a capacity exceeding 1,000 lbs. per hr. or 12 tons per day on 24-hr. operation and will accommodate parts up to 2 in. diameter and 24 in. long. The furnace is gas-fired, with a temperature range up to 1,600 deg. F. Work moves through the three sections (preheating-saturating, quenching, tempering) continuously and mechanically. Four pyrometers and 16 thermocouples regulate and record the heat treating temperatures.

The expanded heat treating facilities thus provided are expected by Horace C. Knerr, Metlab Co. president, to be employed largely for treating parts being manufactured by machine shops, forge shops and foundries in the Philadelphia area who will find their own heat treating facilities inadequate for preparedness requirements.

Steel for Gears and Shafting

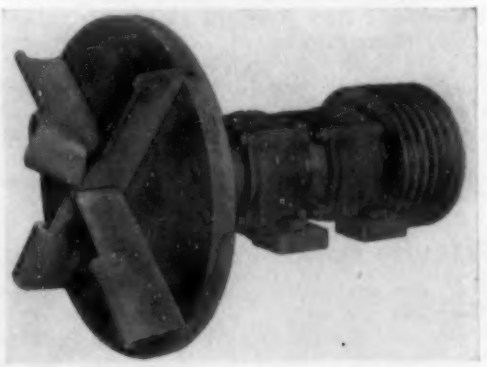
S.A.E. 4815, a nickel-molybdenum carburizing steel (3.25-3.75 per cent nickel, 0.20-0.30 molybdenum) is coming into prominence for heavy duty gear and shafting applications, reports Joseph T. Ryerson & Son, Inc., steel distributors. In the normalized condition, the machining properties of S.A.E. 4815 compare with those of S.A.E. 4615 and S.A.E. 2315, as does the distortion during heating; carburizing practice is much the same as for S.A.E. 2315.

An outstanding advantage of S.A.E. 4815 is the high core strength that may be developed by the single quench treatment from above the core's critical temperature after slow cooling from the carburizing temperature. In sections up to 1 in. tensile values of 200,000 lbs. per sq. in. and yield strengths of 165,000 lbs. per sq. in. may be developed in the core, together with hardnesses up to 415 Brinell, it is said.

The steel is recommended for heavy duty parts such as gears, pinions, splined shafts, and other stressed parts of trucks, aircraft engines, tractors, machines, oil field equipment, and similar applications. This alloy steel is carried in stock by Ryerson in hot-rolled rounds (not annealed) in diameters ranging from ½ in. to 6 in., inclusive.

New Airless Blast Cleaners

Two brand-new massive pieces of cleaning equipment—the new Sly Centriblast rotary mill and the Centriblast rotary table—are offered by W. W. Sly Mfg. Co., Cleveland. These units, representing this company's entrance into the airless blast cleaning field, are said to provide more effective blasting and lower operating costs.



These advantages are claimed to center chiefly in the blasting wheel, illustrated herewith. Abrasive is fed to the wheel in a simple, unique manner, with initial velocity produced by a small blower; this distributes the abrasive uniformly over the blast wheel blades. All wearing parts at the abrasive feed point are eliminated. Blades are so designed and fastened that they can be changed in a jiffy.

The Sly Centriblast rotary mill is for cleaning rugged castings, and the Sly Centriblast rotary table for more delicate, flat and intricate castings.

Electric Arc Furnaces

We are privileged to announce that the Swindell-Dressler Corp. of Pittsburgh has to date (June) installed 74 electric arc melting furnaces in the United States in the iron and steel field and that the smallest of these are making between ¼- and ½-ton heats. Of these, 54 are located in iron and steel foundries. This supplements and corrects the information given in the Table on page 100 of our April issue.

Honors and Awards for Metallurgical Engineers

James H. Critchett, vice president of Electro Metallurgical Co. and of Union Carbide and Carbon Research Laboratories, Inc., New York, has been appointed a member of the National Research Council . . . Wm. M. Barr, chief chemical and metallurgical engineer, Union Pacific Railroad Co., Omaha, Neb., was elected president of the American Society for Testing Materials at its annual meeting last month . . . Paul D. Merica, vice president and director, International Nickel Co., Inc., New York, was elected to the executive committee of the same society, as was Jerome Strauss, vice president of Vanadium Corp. of America, New York . . . Richard L. Templin, chief engineer of tests, Aluminum Co. of America, Pittsburgh, was awarded an Edward Longstreth medal by the Franklin Institute on May 15th, in recognition of his invention of a deformation-recording apparatus.

From Soy Bean to Foundry Core

From the farm to the foundry is the abbreviated story of "Soycl", a foundry core oil made from soy beans, recently introduced by Velsicol Corp., Chicago.

Tests over a period of years are said to show many advantages for this product as a core oil —it works freely in the core boxes without sticking, is as quick baking as other types of binder, will stand more overbaking, gives maximum strength and does not deteriorate the molding sand.

The price of Soycl is described as reasonable, and its supply as practically unlimited, since there is no limit on potential soy bean acreage in this country. The illustration shows an intricate motor block core, as made with Soyol, in a large automotive foundry.

Remote Control for Arc Welders

A new device for remote control of Wilson "Hornet" arc welders is announced by Wilson Welder & Metals Co., Inc., 60 E. 42nd St., New York. A single control of the Hornet welder is well adapted to operation by this new method. To utilize the device, the hand wheel that governs the control pole of the standard Hornet welder is simply replaced by the reversible motor-driven remote control device (type SC).

Said to cover the entire range of the machine to which it is attached, in both high and low settings, the new device allows minute adjustments in current output by merely touching one of two contacts on the electrode holder to the ground. When the electrode holder button marked "more" is brought into contact with the ground, the electric motor in the remote control housing on top of the machine revolves and raises the control pole core, increasing the output. The motor revolves only while actual contact is maintained. When the button marked "less" is grounded, the remote control motor revolves in the opposite direction and lowers the control pole core, decreasing the output.

● According to Allegheny Ludlum Steel Corp., the largest silicon steel sheet ever rolled—64 in. x 64 in., 29 gage—has just been produced at their Brackenridge, Pa. plant.

Lance Pyrometer

The Hold-Heet pyrometer, manufactured by Russell Electric Co., 343 West Huron St., Chicago, is now produced with a new black "crackle" finish, which is impervious to oil and avoids the tarnishing troubles of bare metal.

The Hold-Heet pyrometer can be used for checking temperatures of molten tin, lead, brass, for measuring the higher surface temperatures of billets, slabs, forgings and for testing temperatures of ovens, hot plates, and so on. The instrument reads directly, has manual cold end adjustment, and employs heavy six-gage wire thermocouples.

Another Hollow Electrode Furnace

Among many improvements at the Buffalo foundry of Allegheny Ludlum Steel Corp. is the installation of another hollow electrode furnace. This new electric melting furnace is smaller than the hollow electrode units that this company has had in operation for the past two years, but is otherwise similar. All are of the tilting type and rotate around the hollow electrodes.

These furnaces are the only ones in the world of this particular construction, and are said to produce unusually sound, highly machinable castings. The new small furnace will be employed for stainless steel castings from ½ to 20 lbs., while the large furnaces will be available for increased production of large stainless steel castings weighing several tons.

Electronic Pyrometer Controller

Moving parts in the control circuit—such as motors, depressor bars, toggle switches and open contacts—are completely eliminated in a new electronic pyrometer controller developed recently by the Bristol Co., Waterbury, Conn.

The pointer of the Weston millivoltmeter movement is left free to continuously indicate the temperature under control, it is said. A cold-end compensator insures high accuracy. Control is accomplished by means of a new electronic circuit, using a single high-output vacuum tube of the all-metal type.

Because of the Bristol's Millivac Relay, the controller is reported to be extremely sensitive to changes in temperature at the thermocouple. The entire operating mechanism of this relay is totally enclosed in a vacuum.

Lead-Sodium Alloys

Lead-sodium alloys are being manufactured in commercial quantities, according to an announcement from the R & H Chemicals Dept. of E. I. du Pont de Nemours & Co., Wilmington, Del. Such alloys are used as master alloys or addition agents to harden, modify grain structure, deoxidize and refine non-ferrous metals.

One of the alloys, marketed under the name "Hydrone", is a solid lead-sodium alloy containing about 31 per cent sodium in virgin chemical lead. It can be easily melted and diluted with molten lead to prepare alloys of lower sodium content, thus avoiding the difficult operation of adding sodium directly to lead.

A smooth evolution of hydrogen is obtained when small lumps of Hydrone are immersed in water. The product can therefore be used in field welding and other places where a supply of pure hydrogen is required.

● Tank linings of vulcanized rubber are being increasingly applied to sheet metal tanks and vats used in pickling and plating and for storing corrosive chemicals. Today almost 100 per cent of the pickling tanks used in connection with continuous rolling mills are rubber-lined. Companies active in this field include B. F. Goodrich Co., Goodyear Tire & Rubber Co., U. S. Rubber Co., American Hard Rubber Co., and Manhattan Rubber Co.

● An innovation in outdoor advertising, involving metals, is the "Outdoor Muralad System" of Photographic Display Corp., 45 W. 45th St., New York, which comprises the use of color-photo-murals recessed and housed in an all-metal display unit.

New Permanent Magnet Alloy

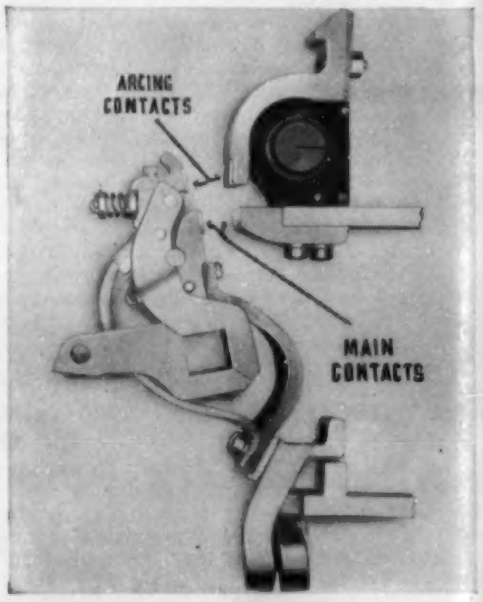
"Vicalloy", a new permanent magnet alloy of unusual properties, has been developed by E. A. Nesbitt and G. A. Kelsall of Bell Telephone Laboratories, New York. The alloy contains 6-16 per cent vanadium, 30-52 per cent iron, and 36-62 per cent cobalt, and can be made to hold more permanent magnetism than any other commercial material, it is said.

In addition, it can be drawn and rolled—a property not possessed by other important permanent magnet alloys. Vicalloy tape 1/500 in. thick and 1/20 in. wide is used for sound recording at the New York World's Fair. In its manufacture, the alloy is cast into ingots, hot-swaged to ¼ in. diameter rod and then drawn into wire or rolled into tape.

When in final form, it is heat treated to develop its maximum magnetic qualities. Heat treatments can be used for this purpose that are harmless to most high-permeability materials, which can therefore be welded to the magnet and the whole assembly heat treated together.

Contacts for Circuit Breakers

A new contact structure, employing Gibsiloy Grade A-3 on the main contacts, has been developed by the I-T-E Circuit Breaker Co., Philadelphia, for their new Type KB Circuit Breakers. The main contacts, as shown in the illustration, consist of silver-nickel blocks elec-



trically brazed to heavy copper bars.

The main contacts were supplied by the Gibson Electric Co., 530 Blvd. of the Allies, Pittsburgh, manufacturers of Gibsiloy ductile contacts from powdered metals. Gibsiloy Grade A-3 (85% silver and 15% nickel) was specified for the new Type KB Circuit Breaker because of its low contact resistance and high conductivity over a long period of time, resulting in minimum temperature rise under overloads. In addition, Gibsiloy is said to have high resistance to wear—an important advantage. Grade A-3 is only one of the several grades of Gibsiloy powdered metals used in the production of electrical contacts.

Stainless Steel Plumbing Fittings

A real challenge to the supremacy of plated metals for plumbing fittings seems to be at hand, with the introduction on a commercial scale of "pickle-polished" (electropolished) *stainless steel* plumbing fixtures by the Schaible Foundry & Brass Co., Cincinnati, Ohio.

Made of Armco stainless steel, and available in either a mirror or silvery-satin finish, these stainless steel kitchen fittings have no plating to peel or wear off. The electrolytic "pickle polish" finishing process (the particular process used here is a joint development of American Rolling Mill Co. and Rustless Iron & Steel Corp.) gives the desired luster to the "mirror" grade without costly hand polishing, thus permitting the prices of the new type of fittings to be competitive with similar plated units, it is said.

(Continued on page 58)

"A.W." *Quality* PRODUCTS *from Mine to Consumer*

Carbon, Copper or Alloy Steels—in *any* Open Hearth analysis, in *any* quantity—to meet *your* specifications . . . Welding qualities, toughness, abrasion resistance, ductility . . . There is an "A.W." Steel made to Alan Wood standards that will give you best results at the lowest possible cost.

"SWEDE" PIG IRON
Foundry, Malleable and Basic.

INGOTS
Standard and special sizes in any Open Hearth analysis.

BLOOMS, BILLETS AND SLABS
Alloy, Forging and Rerolling.

SHEARED STEEL PLATES
Special Alloy, Tank, Ship, Boiler, Flange, Firebox, Locomotive Firebox, Structural and Dredge Pipe.

HOT ROLLED SHEETS
All qualities, special Alloy, Annealed, Blued Finish, Hard Red, Pickled, or deoxidized.

FLOOR PLATES
For every kind of flooring condition: "A.W." Super Diamond, Standard Diamond, Diamondette, Sunken Diamond and Ribbed Patterns. Any pattern furnished in ferrous or non-ferrous analysis.

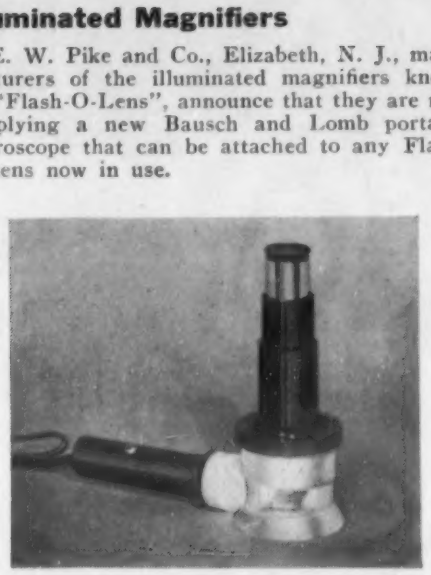
CUT STEEL NAILS
"Reading" Brand—all types and sizes.

ALAN WOOD STEEL COMPANY

MAIN OFFICE AND MILLS, CONSHOHOCKEN, PENNA. : : SINCE 1826 : : DISTRICT OFFICES AND REPRESENTATIVES—Philadelphia, New York, Boston, Atlanta, Buffalo, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, New Orleans, St. Paul, Pittsburgh, Roanoke, Sanford, N.C., St. Louis, Los Angeles, San Francisco, Seattle, Montreal—A. C. Leslie & Co. PRODUCTS INCLUDE—Steel Products in Carbon, Copper or Alloy Analyses : : Sheared Steel Plates : : Hot Rolled Sheets and Strip : : "A.W." Rolled Steel Floor Plates : : Billets, Blooms and Slabs : : "Swede" Pig Iron : : Reading Cut Nails.

Illuminated Magnifiers

E. W. Pike and Co., Elizabeth, N. J., manufacturers of the illuminated magnifiers known as "Flash-O-Lens", announce that they are now supplying a new Bausch and Lomb portable microscope that can be attached to any Flash-O-Lens now in use.



A graduated scale reading to thousandths of an inch is incorporated in the body tube. Magnification up to 40 X is available, with the added feature of illumination of the object, by dry cell or electric current.

Metal-on-Metal Surface Coatings

Simple application, efficient bonding, high metal-protection factor, and low cost are said to be the advantages of a new metal-surfacing process, known as "Colaweld Mormetal." It consists in the deposition and alloying of any one of a selected number of metals, such as zinc, cadmium, tin, bismuth, lead or their alloys on a ferrous or non-ferrous metal base. The method does not involve eletroplating, hot dipping, metal spraying or painting as any of these is generally understood. Application of Colaweld Mormetal is effected by spray, brush or powder followed by subsequent heating.

High speed of application and simple control of deposit thickness are other advantages claimed for the new process. It is of particular value in the marine, transportation, building equipment and metal-working industries, according to The Colonial Alloys Co., Philadelphia, who have develcped it.

Electroplating Non-Conductors

A surface treatment for non-conducting materials such as phenolic products, wood, ebonite, etc. that permits them to be electroplated has been developed and patented by Acheson Colloids Corp., Port Huron, Mich.

The treatment consists in applying to the part a coating containing a hardenable organic colloid, a hardening agent and colloidal graphite, suspended in water, by dipping, brushing or spraying. The coating hardens on exposure to light and renders the surface conductive, permitting the electrodeposition of copper, for example.

New Small Arc Welder

A new welder, the P & H Hansen WD-150, recently placed on the market by Harnischfeger Corp., Milwaukee, Wis., measures less than 33 in. in length and 1 ft. in height, yet delivers uniform welding currents from 200 down to 15 amps.

Current selection is simplified by a single control on this new unit. A revolutionary departure from conventional construction is the square-frame design, which is claimed to permit over-all compactness plus better arrangement of coils, etc.

The P & H Hansen square-frame arc welder is available with stationary or portable mountings.

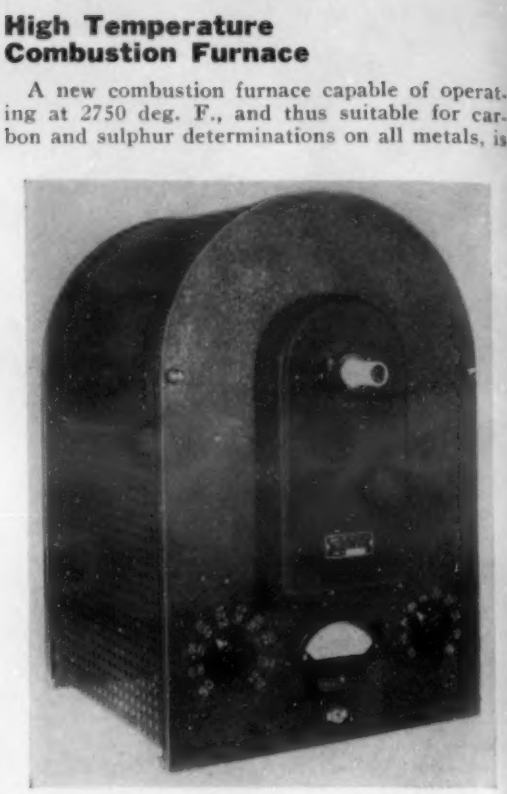
New Contour Shaper

Called the "Super Do-all", the newest model of this all-round machine tool (manufactured by Continental Machines, Inc.) features a new work feed, accommodation for saws up to 1 in. wide, 3 widths of file bands (¼, ⅜ and ½ in.), illuminated magnifying attachment and numerous other improvements.

The new work feed not only draws the work into the saw but mechanically controls the curvature of the cut with a hand wheel. This achievement is a mechanical control that is said to give complete flexibility and superior work dominance, since it eliminates the need for the operator to do hand guiding.

High Temperature Combustion Furnace

A new combustion furnace capable of operating at 2750 deg. F., and thus suitable for carbon and sulphur determinations on all metals, is



announced by Harry W. Dietert Co., Detroit.

Known as the Varitemp combustion furnace, the new furnace has the furnace, transformer, pyrometer, voltage-control switches and power switch all built into an integral unit and housed in a single case, as illustrated. The furnace employs 3 Globar heating elements spaced equidistant around the outside of the combustion tube. A uniform high temperature zone 6 in. long is obtained in the combustion tube.

Rapid (Brush) Silver Plating

An improved portable silver-plating kit listing at $5.00 is announced by Rapid Electroplating Process, Inc., 1414 So. Wabash Avenue, Chicago. Adapted from a larger kit now in regular use by well-known industrial companies, it embodies improvements that enable any inexperienced user to apply lustrous, durable coatings of silver. The patented kit is shipped complete, ready for use and additional compound is available at reasonable cost.

The quality of plate is claimed to be equal to the best commercial plate of equal thickness. No complicated cleaning or acids are necessary and the gel-like compound which contains the silver makes it safe and easy to use on practically any type of article or apparatus.

Some important uses are given as the silver plating of electrical connections to reduce resistance and increase conductivity on radios, electrical instruments, or wherever trouble-free connections are important; the repair and maintenance of laboratory equipment, and the repairing of worn spots before they become serious on all kinds of bright metal products.

Cold Heading Die Steel

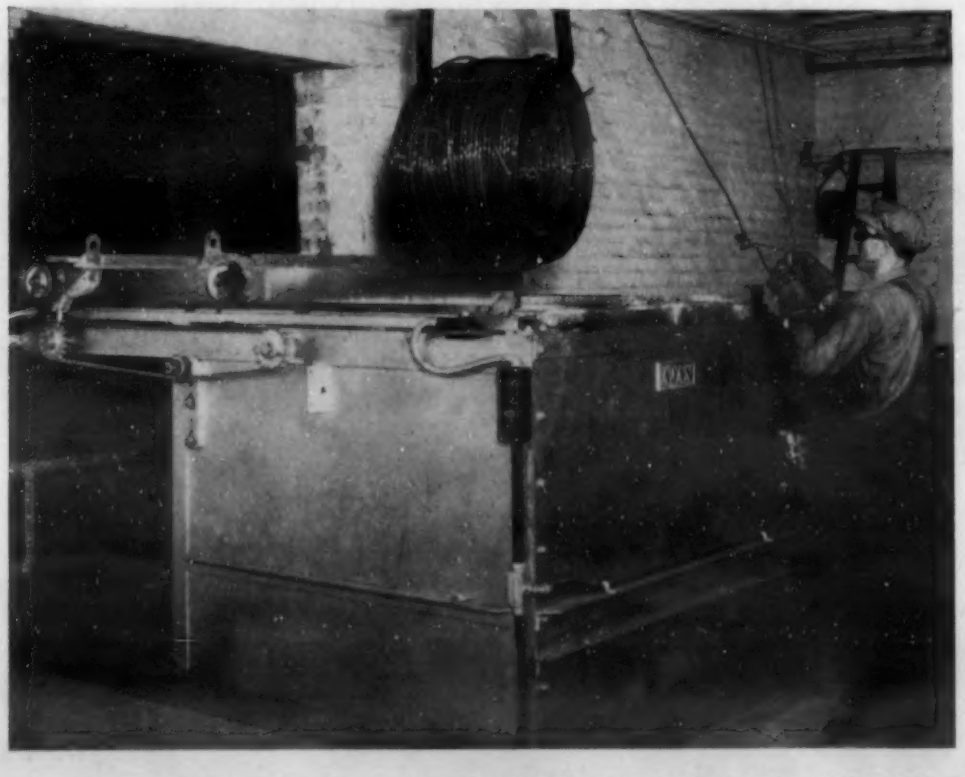
A steel for cold heading dies made by a process that is said to assure completely sound ingots and therefore long tool life, has been developed by Jessop Steel Co., 546 Green St., Washington, Pa.

The steel is recommended by its manufacturer for either solid or open die cold heading work, with no change in regular shop practice. Made in the electric furnace, the new steel has a controlled grain size permitting wide variation in hardening temperature without fear of coarsening.

Experience has shown that a shallow-hardening penetration is best for small dies, and deeper penetration for large. Variations in penetration can safely be effected through variations in hardening temperature, with the new steel.

● A notable feature of the new $2,000,000 Bankers Life Co. building in Des Moines, Iowa, is the 88,000 sq. ft. of enameled steel paneling used for the first time on so extensive a scale as a permanent wall material.

Electric Salt Bath Furnaces for Annealing Wire



The Ajax-Hultgren heating principle, whereby heat is generated directly in a liquid salt bath by means of immersed electrodes without the use of heating elements, has now been applied commercially for annealing wire in coils.

The illustration shows a 150 k.w. unit employed for annealing high carbon steel wire (S.A.E. 52100). The hourly production on this installation is 1500 lbs. The 750-lb. charge is placed in the liquid bath at 1275 deg. F. and is up to temperature within 15 minutes. Temperature uniformity throughout the contents of the pot is said to be within 5 deg. F. This furnace has a working temperature range from 1150 to 1500 deg. F.

Portable Spot Welder

A new, 2-gun, portable spot welding unit expected to eliminate the necessity for duplicate welding equipment, and designed for heavy duty welding requiring high point pressures, large capacity transformer and adjustable weld-time-control for accurate time control, is available from Progressive Welder Co., 3050 E. Outer Drive, Detroit.

The unit illustrated consists of 2 spot welding guns, transformer, air-hydraulic pressure booster, weld timer and contactor. Both the push gun (supplied with grounding clamp) and the scissors-type gun operate from the single transformer mounted in the base of the carriage. Welding point pressures up to 1000 lbs. (for the scissors-type gun) are supplied by the booster mounted above the transformer and operating from the standard factory air line. Other types of guns, too, can be supplied.

Gun Welders in Auto Plants

Claimed to speed assembly, give a structural bond and reduce rejections to a minimum, 17 electronically-controlled gun welders have replaced former methods of assembling automobile body units in some automobile plants.

According to Westinghouse Electric & Mfg. Co., E. Pittsburgh, these gun welders (designed by Progressive Welder Co.), using Westinghouse electronic control, are being used in one modern radiator and grille assembly department to join 20 separate parts at 150 places in less than a minute. Because the gun-welded bonds are stronger, only half as many welds are used, it is said.

Sinter Meter for Foundry Sands, etc.

The Sinter Meter, an interesting improved product of Harry W. Dietert Co., Detroit, is used for determining the refractoriness of molding sands, core sands, clays and refractory materials like mortars and bricks.

Refractoriness is determined by placing the sample under the platinum-rhodium ribbon of the meter. The ribbon is heated to increasingly higher temperatures until the sample touching the ribbon fuses to it, at which time the temperature of the ribbon is read with an optical pyrometer, which is part of the instrument. The incipient fusion temperature, termed the "sintering temperature", can be accurately determined, and the test conforms to A. F. A. specifications, it is said.

● An interesting new surface treatment designed to prevent or minimize corrosion or "furring" of boilers has been developed by Acheson Colloids Corp., Port Huron, Mich. It consists of a coating that may be applied by dipping, brushing or spraying, and that hardens when applied and exposed to light. Basic constituents are colloidal graphite, an electropositive metallic filler, a hardenable organic colloid and a hardening agent for the colloid, suspended in water.

Chemical Surface Treatment

A low-cost, non-electrolytic and simple method of producing a hard, smooth, tenacious, corrosion-resistant and colorless surface on Colalloy alloys and aluminum and its alloys is now available in the "Chemodizing" solution and process, according to Colonial Alloys Co., Philadelphia.

The Chemodizing solution is supplied ready for the operator to mix with water, and the process is substantially a simple immersion operation that does not require the use of electricity or its appurtenances. The use of heat in the process is optional, and time, which is not a critical factor, may range from 5 min. to 20 hrs. Prior degreasing and cleaning are said to be unnecessary, and the solution itself is neither toxic nor unpleasant to work with.

The surface resulting from Chemodizing is described as almost flint-hard, very corrosion-resistant and an excellent base for paints lacquers, oils, etc. The process is applicable to all the foregoing alloys in their usual cast or wrought form.

Drop Forging Hammer

A new type of pneumatic drop forging hammer, known as the "Double Action" hammer, has been developed by Pneumatic Drop Hammer Co., Braintree, Mass.

The ram is lifted by air and dropped by gravity, with the anvil automatically propelled upward at the proper time to meet it. The motions of ram and anvil are reversed at impact of opposing dies, and it is said impact forces are so well equalized that the supporting structure suffers no shock or vibration.

● Colored rust-proofing for iron and steel, developed by Rust Proofing & Metal Finishing Corp., Cambridge, Mass., serves to eliminate mistakes and confusion in assembling parts and to provide a variety of final finishes.

● The Copper and Brass Mill Products Ass'n. and Copper and Brass Research Ass'n. have been merged under the name of Copper and Brass Research Ass'n., the address remaining 420 Lexington Ave., New York.

Special Process Iron for Crane Brake Wheels

Heavy duty crane brake wheels are now being cast in Meehanite Metal as a result of recent experiments undertaken by the Meehanite Research Institute, working in cooperation with the Meehanite foundries in the United States. Illustrated are four different types and sizes of these wheels cast by Rosedale Foundry & Machine Co., Pittsburgh, Pa. The brake

wheels illustrated range from 21 to 27 in. diameter.

All brake wheels shown are cast in GA Meehanite, having a tensile strength of at least 50,000 lbs. per sq. in. and a Brinell hardness of approximately 220. Service reports are said to show that these wheels possess improved freedom from distortion and resistance to glazing.

● On display at the West Virginia building at the New York World's Fair is the smallest metal tube ever produced—a pure nickel tubing with an outside diameter of 0.0019 in. and a wall thickness of 0.00075 in. The tube was drawn by Superior Tube Co., Norristown, Pa., from larger tubing produced at the Huntington, W. Va. plant of the International Nickel Co.

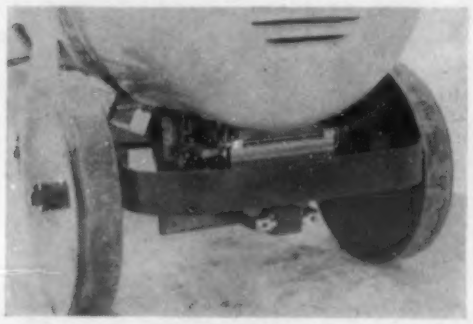
Magnesium Alloy Safety Blocks for Forming Presses

Extruded magnesium alloy (Dowmetal) safety blocks for sheet metal forming presses are being increasingly applied, according to Dow Chemical Co., Midland, Mich., because of their light weight and greater safety.

Their light weight is said to be an advantage over steel for the same purpose, and their greater strength a safety advantage over oak blocks, which have often lacked the strength to withstand loads in medium and large presses if the latter were accidentally tripped. The Dowmetal blocks provide complete safety in die openings while men are working on the presses, as illustrated, it is said.

Automatic Start-Stop Device for Arc Welders

In an effort to eliminate the waste incurred from frequent idling of an arc welder between jobs, the Wilson Welder and Metals Co., Inc., 60 E. 42nd St., New York, has developed a new automatic start-and-stop device, for use on



any magnetic-starter, motor generator arc welder, such as the Wilson "Hornet," driven by an a.c. motor.

With the new device, the operator starts the welding unit simply by touching the work with his electrode holder. When welding is interrupted, the machine automatically stops after a time delay which may be set for ½-1½ min.

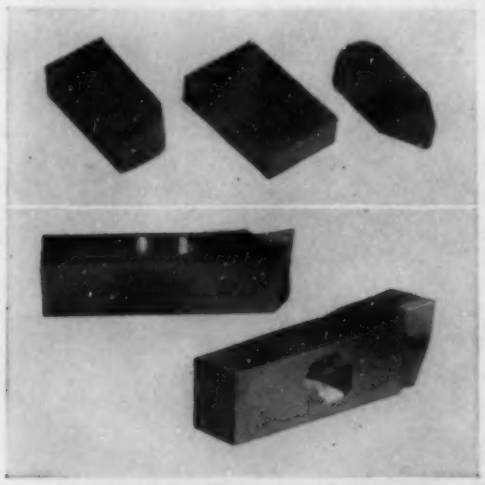
The standard device is reconnectable for 220 or 440 volts, or it may be supplied for other a.c. (60 cycle) voltages.

New Grade of Tungsten-Titanium Carbide

A new grade of Kennametal tungsten-titanium carbide alloy, claimed to combine unusual hardness with great toughness, has just been announced by McKenna Metals Co., 158 Lloyd Ave., Latrobe, Pa.

The hard tool composition (Kennametal grade K3H) is recommended as a tool tip material for light finishing cuts and for fairly heavy continuous cuts on steel of all hardnesses up to 550 Brinell. Tool tips of this material are supplied in the three standard shapes shown at the top of the illustration, or in special shapes made to specification. Tools on which tips have already been brazed are also furnished.

Because of its extreme hardness, Kennametal K3H will produce more pieces per grind than the usual hard carbide tool material, it is said. Boring tools tipped with this grade of Kennametal (shown at bottom of illustration) are reported to have produced 200-225 pieces per



grind of tool, as compared to 40-75 pieces for other carbide materials. The material machined was S.A.E. 1020 forged and carburized steel, which Kennametal cut at 406 ft. per min.

● The F. A. Reynolds Co., Cleveland, manufacturers of band instruments, have speeded-up their spinning operations by employing spinning-forms cast-to-shape in Meehanite metal, reports the Meehanite Research Institute, Pittsburgh.

● The fifth annual progress report of the Society for the Promotion of Engineering Education, released last month, states that recent notable increases in undergraduate engineering enrollment is "mainly due to the growing regard for engineering training as a preparation for careers in industry, business and public service". Amen!

Electrogalvanizing Generators

Low voltage generators as used for electroplating, electrotyping, electrorefining, etc., are fairly well standardized. The extension of the commercial field of electrodeposition to include the electrolytic galvanizing of steel wire, however, has introduced many new problems, associated primarily with the large scale of operations.

Electrical machinery for this purpose has recently been furnished by Hanson-Van Winkle-Munning Co., Matawan, N. J., one set being one of the largest and most efficient motor generator sets ever produced for electroplating or other low-voltage service. The set consists of 1 main driving synchronous motor coupled to 3 plating generators with an engine-type exciter. The motor is rated 1750 h.p., unity power factor, 6600 volt, 60-cycle, 3-phase, 257 r.p.m. Each of the 3 main plating generators is rated at 7500 amps. and 36 volts.

Joining Aluminum and its Alloys

The joining of aluminum or aluminum alloys to each other or to other metals has always been something of a problem, declares Colonial Alloys Co., E. Somerset, Trenton Ave. and Martha St., Philadelphia. Such operations are said to be materially simplified by the use of "Colaweld Metaljoiner", a product of this company.

The joint produced is described as the result of fusion of molten Colaweld Metaljoiner with, and its alloying deposition on, the surfaces of the metals to be joined. The strength and ductility of the joints are said to be good, and light gages can be joined because of the low temperatures used.

The procedure comprises applying the Metaljoiner in powder or paste form to the surfaces to be joined, placing these together and applying heat. When the metal in the compound melts, the excess compound is removed and the work cooled by air or water quenching. No separate fluxes, solders or welding rods are necessary.

Standardized Spot Welding Machines

The purchase of spot welding machinery has generally been on a basis of special equipment for special jobs, with resultant proportionately high investments in equipment for an otherwise inexpensive assembly method.

Now, however, the American Electric Fusion Corp., 2610-2622 Diversey Ave., Chicago, is introducing a line of standardized spot welding machines. By standardizing on 3 sizes of frames, all of which bear the same design characteristics and interchangeable parts wherever possible, spot welding machines for a wide range of applications are now available on a mass production scale, it is said. The standardized line of spot welders ranges in electrical capacity from 10 to 50 KVA.

The reduced production costs resulting from this standardization program has, it is stated, enabled the manufacturers of these welders to appreciably reduce their prices.

New Rocking Furnace Features

Recent improvements in design and construction of Detroit indirect arc rocking furnaces, manufactured by Detroit Electric Furnace Div. of Kuhlman Electric Co., Bay City, Mich., should be of interest to engineers, metallurgists and foundrymen engaged in melting ferrous or non-ferrous metals.

All Detroit furnaces are now equipped with the new type AR-1 automatic rocking controller as standard equipment. All LF type furnaces during 1939 and 1940 have been equipped with the new sliding contact cable connectors. Since April 1, 1939 all new LF installations have been equipped with newly designed electrode brackets—both manual and automatic.

Among the most important refinements have been changes in shape and proportioning of shell and hearth through the use of conical shell design. The interior of the furnace conforms with the natural shape of the melting chamber, with many resultant economies to the owner as compared with the cylindrical shell design.

Meetings and Expositions

AMERICAN CHEMICAL SOCIETY, fall meeting. Detroit, Sept. 9-13.

AMERICAN MINING CONGRESS, annual western convention and exposition. Colorado Springs, Colo., Sept. 16-19.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Spokane, Wash., Sept. 3-6.

ASSOCIATION OF IRON AND STEEL ENGINEERS, annual meeting and exposition. Chicago, Sept. 24-27.

NATIONAL METAL CONGRESS AND EXPOSITION, Public Auditorium, Cleveland, Oct. 21-25.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, fall meeting. Seattle, Wash., Aug. 20-21.

Moisture Testing

A new line of moisture testers, known as the "Delmhorst Moisture Detectors," employing an electrical principle of measurement, is being offered by Colloid Equipment Co., 50 Church St., New York.

The new instrument actually measures the electrical resistance of the material being tested, and since the amount of this resistance is usually a fraction of the amount of moisture present, the latter can be measured more or less directly after calibration. Tests are made instantly, merely by pressing electrode needles into the material, pressing a button or turning a knob and reading the degree of moisture present on a dial.

Both surface and sub-surface moisture can be detected, and the needle points of the electrode penetrate below the surface of the material without marring its finish. The equipment has potential applications in testing foundry sand, clays for ceramic and refractory products, insulation, and other materials.

Economical Electric Annealing

Savings of 25 per cent in the cost of annealing forged steel unions, with simultaneous improvement in the strength and uniformity of product, are benefits reported by the Rockwood Sprinkler Co.'s plant at Worcester, Mass. since the installation of a Westinghouse continuous electric furnace equipped with atmospheric control. The unions, ranging from ⅛ to 3 in. pipe size, are annealed between forging operations. The electric furnace replaces two previously-used oil burning furnaces and, because of its faster operation, has eliminated a serious plant bottleneck, it is stated.

The electric furnace is a 90-kw. unit, approximately 50 ft. long and handles 250-lb.-capacity trays moved through the furnace's 3 temperature zones by an hydraulic pusher. The atmosphere is produced by burning city gas and air and feeding the product of combustion into the annealing chamber.

Free Service Department

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd St., New York.*

POSITION WANTED: Chemist and metallurgist, 33 years' experience grey iron, malleable iron, steel. Can handle any foundry problem, analyses, melting, iron mixtures, annealing, heat treating, sand control. Box MA-18.

MANUFACTURERS' AGENT AVAILABLE: A graduate engineer from Johannesburg, South Africa, is in this country arranging to establish himself as manufacturers' agent, for South Africa, of reliable American and Canadian manufacturers. Especially qualified to handle drill and tool steels, electric motors, tools, scientific instruments, electrical appliances and office machines. Box MA-19.

WANTED: Metallurgist 25 to 35 years of age, with practical foundry experience, grey iron preferred, for sale of established alloy used in grey iron and steel castings. State age, experience and salary expected. Box MA-20.

POSITION WANTED: Physical metallurgist, four years' experience in powder metals with graduate courses and research work this year. Box MA-21.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

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Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

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4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

1 Production

OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

Continuous Casting

A Composite

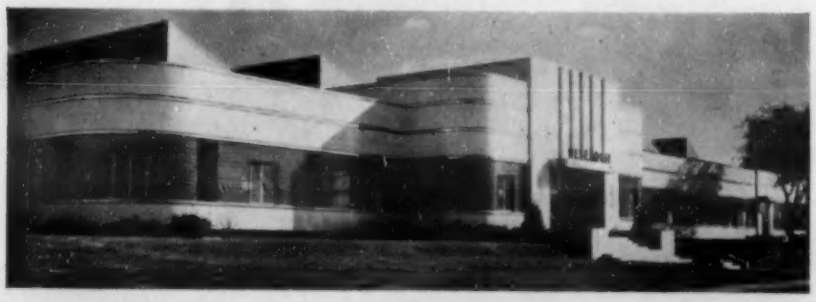
Continuous casting, direct rolling, roll-casting (whatever your preference), the process of producing billet, bar or sheet without going through the ingot stage, is a basic metal-producing system of obviously challenging interest. Many inventors and metal manufacturers have spent much of their time and money on various continuous casting devices in the hope that some day an important portion of their production will be on a basis that eliminates the use of expensive molding, mold-storage ingot-soaking, cogging, reheating and rolling equipment. The present status of several of these processes is reviewed in two recent articles in American magazines.

The five most important billet or bar processes of current interest in this country, according to T. W. LIPPERT ("Continuous Casting," *Iron Age*, Vol. 145, Apr. 4, 1940, pp. 31-39; Apr. 11, 1940, pp. 44-47), are the Junghans process, the Williams method, the Eldred system, the Poland process of American Smelting & Refining Co., and the Aluminum Co. of America's process. Most important among the strip or sheet processes are the Hazelett casting rolling-mill, the Hazelett strip-casting unit and the Merle process.

The Junghans machine is used with non-ferrous metals. Molten metal is bottom-poured into a sealed holding-furnace in an inert gas atmosphere. A U-tube extends below the metal surface in the holding-furnace and carries the metal into the feeding chamber, from where it passes into the mold by gravity feed through the bottom. The mold is ordinary drawn copper tubing with about ½ in. wall thickness, and may be round (up to 18 or 20 in. diameter), square or rectangular.

The red-hot billet coming from the mold is cooled by a water spray. A 7⅞ in. diameter billet (for example), comes out at the rate of 10 in./min. The temperature of the metal in the mold is about 135° F. lower than the temperature of metal poured into a conventional ingot mold. There is no scarring or erosion of the copper mold.

For continuous casting of steel, the Williams process, primarily concerned with mold design and cooling, accomplishes heat removal by providing a very thin mold wall of high-thermal-conductivity metal such as copper or brass tubing. The metal freezes



IN THE WORLD'S LARGEST PORCELAIN ENAMEL BUILDING

The new research laboratory of The American Rolling Mill Company at Middletown, Ohio, is "all-electric" and is said to be the world's largest porcelain enamel building.

Experimental heats of iron and steel are melted down in small Ajax-Northrup High Frequency Furnaces with current supplied by a 35 KVA Ajax-Northrup Converter.

For larger melts they use Ajax 250 and 500 lb. furnaces and a 100 KW high frequency motor generator.

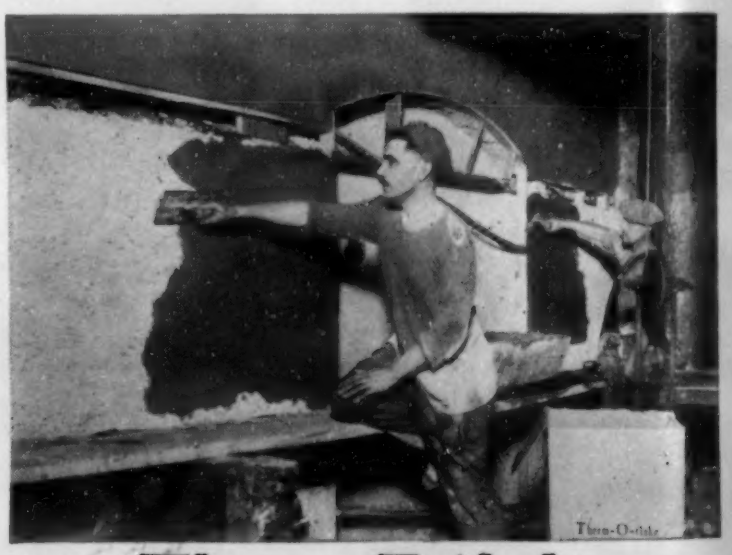
Accurate control, flexibility and the fact that a large number of test melts can be made in a comparatively short time are the principal advantages of the Ajax-Northrup Furnace.

ASK FOR BULLETINS T-5 AND T-6.

Ajax-Northrup Melting Furnace Capacities: One Ounce To Eight Tons

AJAX ELECTROTHERMIC CORPORATION
AJAX PARK TRENTON, N. J.

AJ-23-A



Therm-O-flake COATING

SUPERIOR HIGH TEMPERATURE INSULATION

Keeps heat inside, with a coating of plastic insulation.

One inch thickness equivalent to about nine inches of fire brick wall in insulation value.

More economical in cost and installation, on existing furnaces, than walls of insulation brick.

Easily applied and largely reclaimable for re-use, after removal.

Most widely used material for high temperature insulation, up to 2000°F.

Write for Information and Prices

Other Therm-O-Flake Products
● Made from Exfoliated Vermiculite
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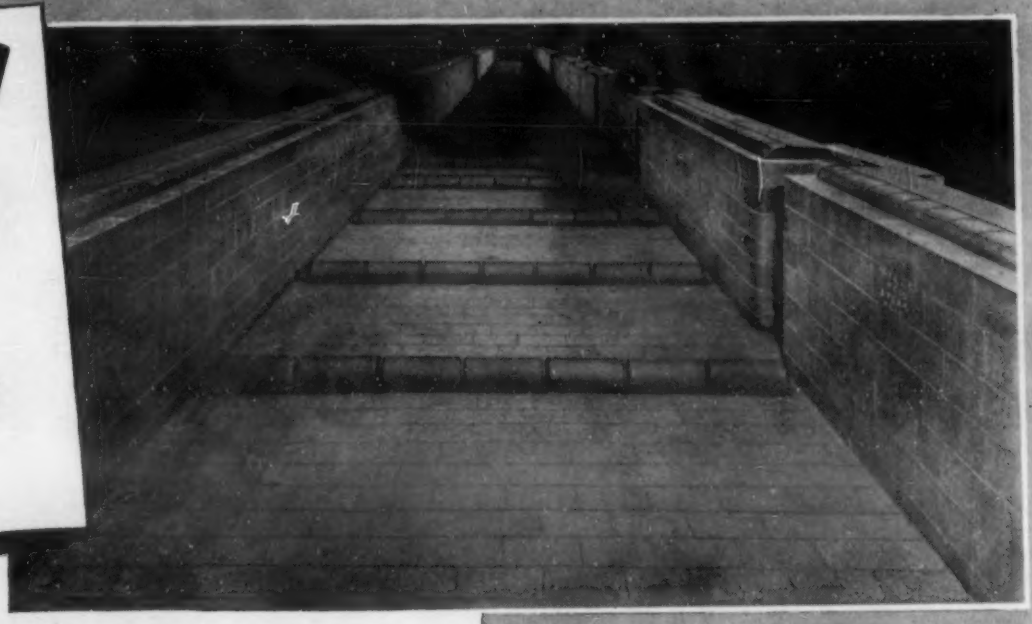
165′ x 9′ x approximately 3′ DEEP



LARGEST INDIVIDUAL *Dual Construction* PICKLING TANK

This continuous pickler for narrow strip steel was recently installed in the Riverdale plant of the Acme Steel Company, Chicago, one of America's largest producers of hot and cold rolled strip steel, cooperage hoops, box strapping, unit load band and various other strip steel specialties. It replaces the old type lead lined wooden pickling tanks.

NEW CONSTRUCTION TO MEET NEW CONDITIONS

Brick lined pickling tanks were formerly built for operating temperatures below 200° Fahr. New conditions call for higher production from same equipment . . . and this means higher operating temperatures.

Dual Construction, developed by Atlas, withstands temperatures to 250° Fahr. The Acme tank pictured above will be operated at well above 200° Fahr., and will not be affected by overheating from *any* operating condition.

TWO NOTABLE FEATURES of its construction are:

(a) Atlas Improved Expansion Joints. (b) New type Skid Blocks with no projections or corners that might break off in service.

Atlas Dual Construction consists of a combination brick lining in which a chemically setting synthetic resin cement called KOREZ is used in the brick course next to the corrosive bath, and molten Tegul-VITROBOND is poured into the joints of the back course of brick. The heat given off during solidification of the VITROBOND converts KOREZ Resin Cement to its final set in a short time. The equipment is then ready for immediate service.

This construction, already in service in a number of America's larger chemical plants, steel mills and metal refinery plants, has proved its superiority.

SIX IMPORTANT ADVANTAGES of ATLAS DUAL CONSTRUCTION

1—Inert to both hot acid and hot lime solutions.

2—Withstands operating temperatures to 250° Fahr.

3—Unaffected by local overheating, whether from faulty steam jets or from heat generated by the addition of concentrated acid.

4—Unaffected by abrasion or turbulent liquids.

5—Construction requires less labor.

6—Resistant to water and oils.

Our Engineering Staff is prepared to submit recommendations and estimates without cost to you—and to construct, or supervise construction of any type of acid-proof equipment. Write for Technical Literature.

Patents applied for on all important features of Atlas Dual Construction

THE ATLAS MINERAL PRODUCTS CO. OF PA. MERTZTOWN, PA. ESTABD. 1902 — THE House of Jointing Materials

Atlas Mineral PRODUCTS COMPANY OF PENNA.

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*DALLAS, Texas 3921 Purdue Street
*LOS ANGELES, Cal. 817 Yale Street
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*Stock carried at these points.

into a skin that shrinks away from the frictional resistance and is strong enough to prevent fracturing as it is moved along the mold wall. Cooled water passes through special passages with small clearance, and at high velocity. The mold is stationary. Williams claims that his process eliminates piping and segregation. Control of solidification is accomplished by cooling sprays.

In the Eldred system, a graphite forming-chamber is used, around which is a cooling chamber through which water is circulated. The crystal structure can be controlled, and usually billets are produced with crystals oriented in the longitudinal direction. The metal is gas-free, very dense and frequently with exceptional mechanical properties as-cast. Scalping is not necessary before additional hot or cold working.

The Poland-Linder machine casts copper and copper-base alloys; the Poland and Eldred designs are quite similar. As regards thermal transfer, Poland-Linder specify cooling of the metal by extraction of heat through the die walls and continuous withdrawal of solidified metal. The mold is of refractory, heat-conducting material, which is not wettable. The die is about 7-8 in. long and the speed of casting is not very high.

Recently, a simple high speed Hazelett machine (described in METALS AND ALLOYS, Vol. 10, Dec. 1939, p. MA 701 L 7) has been tried experimentally. Hazelett's early casting-rolling mill design comprised 2 rolls cooled externally with water sprays, between which the liquid metal is poured. With rolls turning and the pool of molten metal maintained between them, 2 continuous strips of metal are cast. These 2 strips are pressed together and given a certain amount of reduction at the nib of the rolls.

Segregation, evidenced by red surface stains, occurred in brass, however. This was overcome by pouring the metal first on one cooling member, allowing to chill almost throughout its thickness, and then surface rolling to chill and compress the very small film of unsolidified metal. This is done on a new ring mill by pouring the molten metal on the outside of a large rotating ring; the ring surface is first degassed to assure sound metal, and cooling is accomplished at high rates for continuous production.

Details of the Williams process, mentioned above, are given by E. R. WILLIAMS ("Continuous Casting," *Steel*, Vol. 106, Apr. 8, 1940, pp. 48-49, 56, 58, 81). Not only steel, but aluminum and other nonferrous alloys have been successfully cast by this process. With steel, speeds as high as 7 lineal ft./min. have been attained with 4x4 in. ingots. When casting aluminum, the pouring-box nozzle is extended below the level of molten metal in the mold to prevent oxidation, or an inert gas may be used above the molten metal.

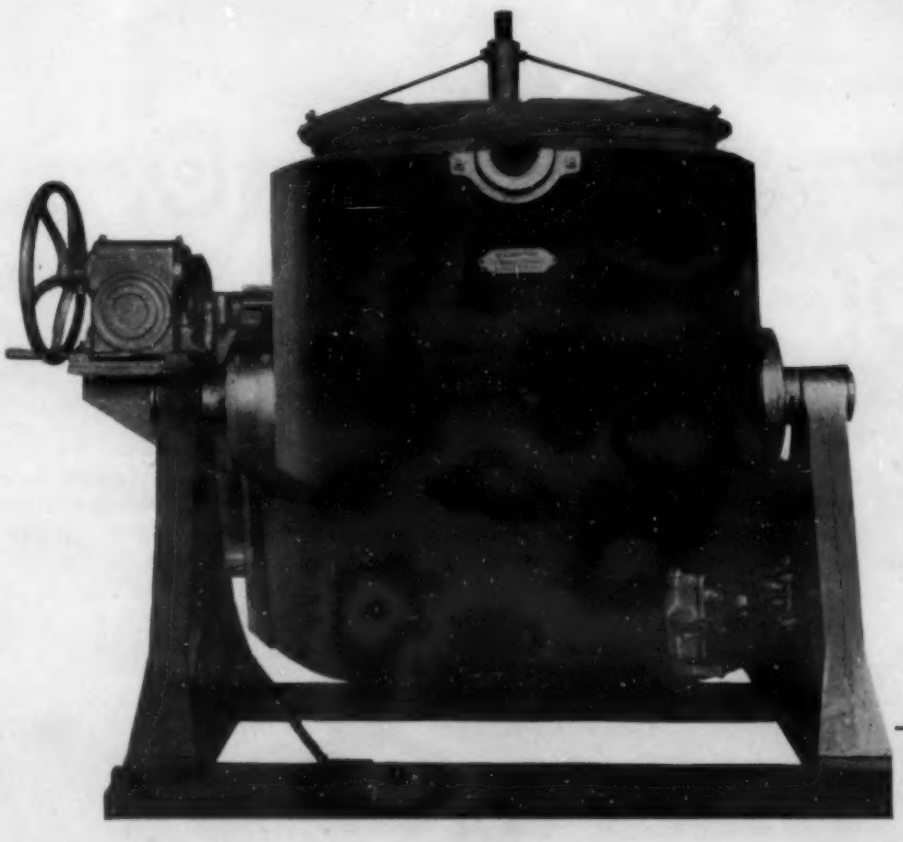
Lippert surveys the commercial standing of these processes. Equipment based on the Junghans process at Scovill Mfg. Co. is producing 1,500,000 lbs. of extruding brass billets each week. Williams' extremely promising mold has still to be given a long run on steel, but a small unit is currently operating on copper at Bridgeport Brass. Eldred licenses are owned by the Aluminum Co. of America and American Smelting and Refining Co.

However, American Smelting and Refining Co. has been producing 3-in. phosphorized copper billets on a large scale for the last 18 months by the Poland-Linder process, and the Aluminum company's process, still a secret, is said to be something of their own design. International Nickel Co. is experimenting with a stationary-mold system employing lubricant forced through apertures in the mold wall during pouring.

American Metal Co. and Scovill Mfg. Co. are jointly experimenting with Hazelett's new ring-type mill, which can turn out metal at 500 ft./min., produces brass comparable in ordinary physical properties with conventionally-made material, and is said to have promise for silicon-steel and stainless steel strip. X (1)

WHY . . .

was this the only furnace capable of accomplishing a ticklish melting job where other types of furnaces had failed . . . . . ?



● FOR FULL INFORMATION . . . ADDRESS

CRUCIBLE FURNACE COMPANY

Charlottesville, Va.

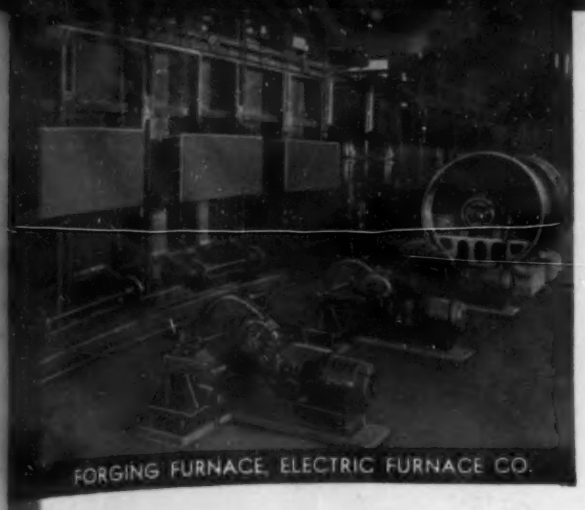
1a. Ferrous

Steelmaking Refractories

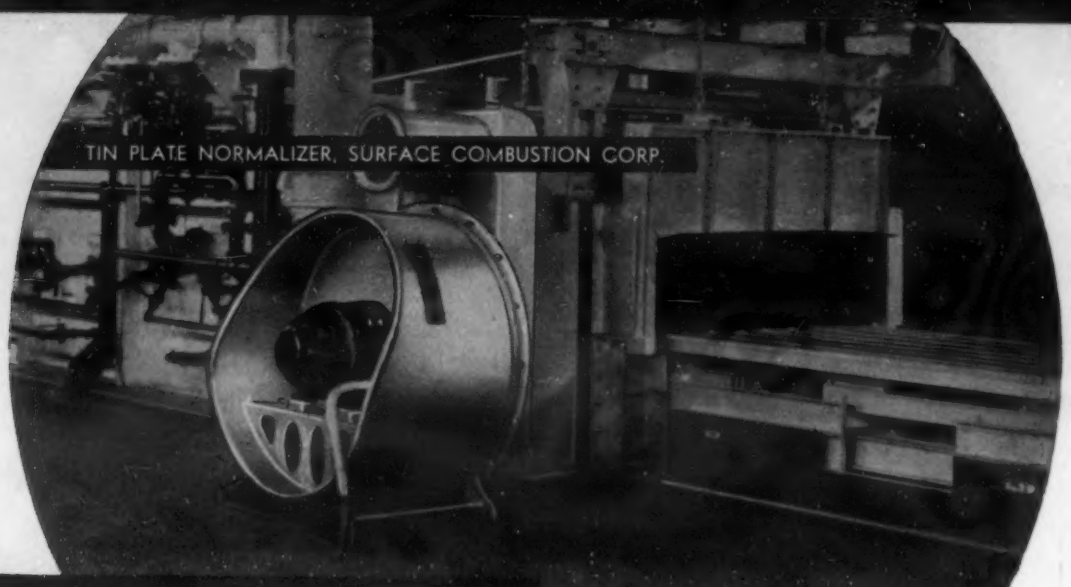
"REFRACTORIES IN THE IRON AND STEEL INDUSTRY." ALAN STEIN. *J. West Scotland Iron Steel Inst.*, Vol. 47, Part I, 1939, pp. 3-9. Informative survey.

The design and efficiency of any furnace is closely related to the refractories available at a reasonable cost. Use of a standard 9 x 4½-in. brick with a thickness of 3 in. instead of 2½ in. has been gaining favor in the United Kingdom and slowly in other countries. Special shapes are sold on a volume basis. It is an advantage to design shapes so they can be made by machine. Special shapes can be ground from stock material in an emergency or where extreme accuracy in shape and size is necessary. Insulation allows a savings in fuel and more rapid heating to high temperature, but it usually means more severe conditions for the refractories because the cooling gradient is less steep and there is more chance of creep or deformation under load.

Mellor once defined the ideal refractory as being "as refractory as carbon, as hard as steel, and as cheap as road rakings." The practical steelmaker would prefer the

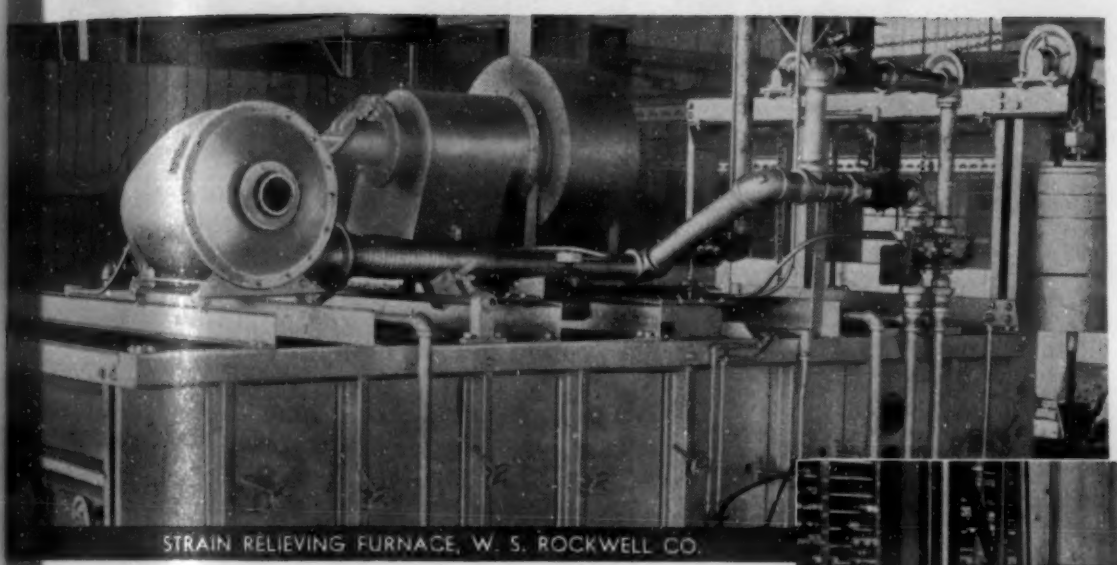


FORGING FURNACE, ELECTRIC FURNACE CO.

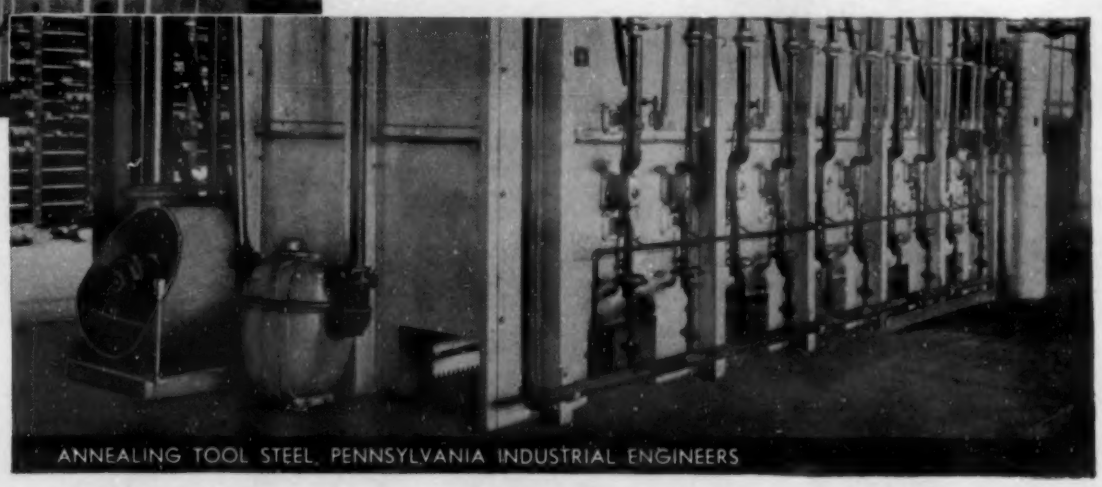


TIN PLATE NORMALIZER, SURFACE COMBUSTION CORP.

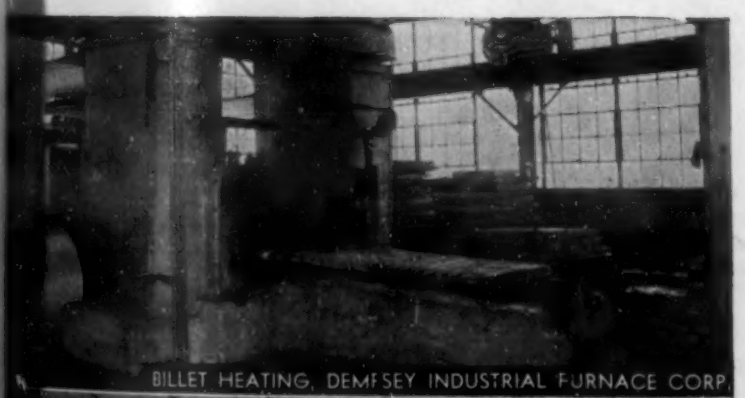
HEATING



STRAIN RELIEVING FURNACE, W. S. ROCKWELL CO.



ANNEALING TOOL STEEL, PENNSYLVANIA INDUSTRIAL ENGINEERS



BILLET HEATING, DEMPSEY INDUSTRIAL FURNACE CORP.

BILLET HEATING, INDUSTRIAL HEATING EQUIPMENT CO.

With SPENCER HARTFORD

TURBO COMPRESSORS

Operators of forging and billet furnaces emphatically demand economical and breakdown free operation, assurance against overheating and "burning" of the stock and freedom from underheating resulting in poor forging stock, damaged dies or expensive waste.

Even in the relatively low temperature furnaces also shown on this page, perfect control of temperatures is a critical factor.

That is why so many furnace manufacturers prefer and recommend the use of the Spencer Turbo-Compressor—the air source that has been distinguished for its reliability, efficient performance and long life for more than a quarter of a century.

ASK YOUR EQUIPMENT MANUFACTURER FOR THE SPENCER BULLETINS

184-C

SPENCER TURBO COMPRESSORS

HARTFORD

35 TO 20,000 CU. FT. ⅓ TO 300 H.P. 8 OZ. TO 5 LBS.

THE SPENCER TURBINE COMPANY • HARTFORD, CONNECTICUT

refractory that gives him the lowest cost of refractories, including labor, per ton of steel produced, although more accurate definition would be, "that which gives him steel at the lowest 'all in' cost."

As the years pass, changes are made in the quality of most brands and the price of efficiency is a periodical review of existing practice. Laboratory tests can be useful in indicating the materials most likely to prove worth investigating. The U. S. A. spalling test for a full panel of 14 bricks costs $80 if the preheat is 2900° F. and $90 if the preheat is 3000° F. America and Germany have done more in the way of standard specifications than most other countries, and Great Britain, with no standard specification, lags behind. In the U. S. A. the panel spalling test is singled out as being of outstanding value with little attention to the underload characteristics, the importance of which are stressed in Germany and France.

Sizing of ore to reduce channelling in the blast furnace and increased water cooling of the shaft will give longer refractory life. High crushing strength and resistance to abrasion are difficult to obtain in the more refractory high-alumina brick; other things being equal, however, the higher the refractoriness the better, and high-alumina gives better resistance to corrosion. There is no damaging carbon deposit in the pores if the iron is fixed as ferrous silicate rather than present as catalytically active iron oxide. Tests on two joining cements and one straight fireclay showed an increase in viscosity and poorer workability with the use of hot water, which is a widely adopted practice in the U. S. A.

The standard practice eventually will be for the whole of the open hearth melting chamber to be built of basic brick. A chrome magnesite brick is capable of withstanding a higher temperature than magnesite and its use permits a thinner working hearth. This gives a larger margin of safety and allows the use of insulation (of high crushing strength) next to the pan. During the week-end shut-down the backwall temperature drops from 2950° F. to 1650° F. This may be detrimental with basic materials of high thermal expansion.

Firebricks are heavier and, with the same specific heat as silica bricks, have an advantage in the tops of checkers which is the most useful portion. High-temperature materials such as insulation bricks should have an advantage for the doors and lining of reheating furnaces. Over a period of years the weight of refractories per ton of steel has decreased, partly due to improved refractories and partly to improvements in design of furnaces and to better control in operation. FGN (1a)

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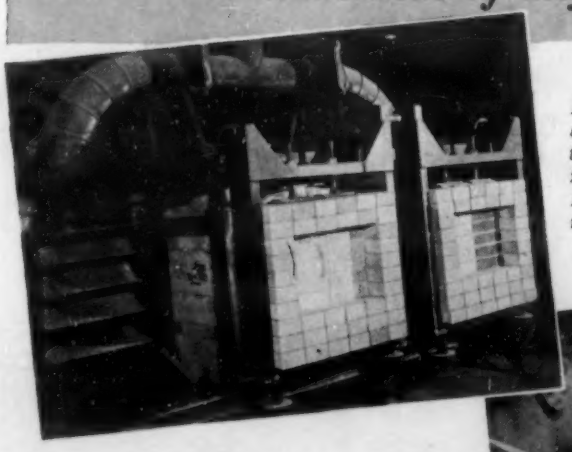

Left—SPALLING RESISTANCE: *The unusually high spalling resistance of Armstrong's Brick is proved in this test which subjects panels of brick alternately to 2000° F. and 1400 c.f.m. of air at 70° F. 10 times in 10-minute cycles following a 24-hour pre-heat at recommended top service temperature for the brick.*

Right—COMPRESSIVE STRENGTH: *Armstrong's Brick are tested in this Olsen machine, which shows they have exceptionally high crushing strength. Heavy-duty brick resist pressures up to 430 pounds per square inch—assurance that Armstrong's Brick will stand up in your furnaces.*

Left—FLEXURAL STRENGTH: *Armstrong's Insulating Fire Brick are tested in this Olsen breaking strength machine to assure uniformly high quality and dependable, lasting performance in your plant. In this test, Armstrong's Brick are subjected to pressures up to 225 pounds per square inch.*

Right—SHIPPING STRENGTH: *In the Kreas tumbling barrel test, actual shipping and handling conditions are simulated by repeated dropping of a full carton of Armstrong's Insulating Fire Brick on every side, corner, and edge. Recently a shipment of 160,000 Armstrong's Brick was delivered with only 100 broken.*

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Automotive Cylinder Castings

"CHANGES METHODS TO REDUCE CYLINDER CASTING LOSS." JOHN E. OLSON. *Foundry*, Vol. 68, May 1940, pp. 88-89, 171-174. Practical.

The cylinders in question weigh from 350 to 4,300 lbs. in size, with from 8 to 24 in. bore, 2½ to 6 ft. length, and ½ to 1½ in. sidewall metal thickness. All were water-jacketed, and were specified to stand temperatures and pressures encountered in internal combustion engines.

In the former practice, split wooden patterns were used, with dry sand molds, rammed horizontally in 2-part flasks, finished and blacked before drying. The molds were dried at about 600° F., cored, closed and placed in an upright position. A barrel core extended above the flask, and the vent was located in the center when pasting 2 half-cores together. Metal was admitted through a circle of pencil gates in the jacket core prints. This method gave excessive scrap and was time-consuming.

A more practical method was to pour the cylinders in a horizontal position, with the metal entering at the bottom and rising around the cores. The pouring basin size is varied according to the amount of metal to be poured. There is a tapered plug in the pouring basin outlet where the latter enters the down gate. When the basin is full the plug is removed. This "trap" permits dirt and slag to rise to the top before flow to casting starts.

As a further precaution a metal skimmer is provided between the gate and the runner to the casting. The horizontal ingress gating system cross-sectional area is largest at the entrance to the casting (being gradually tapered from the base of the down gate to the casting). Thus the flow velocity of the molten metal is least as the metal enters the mold.

The features of this method, as compared with its predecessors, are: The molding remains the same; the coring operation with less chaplets is less exacting; runner boxes are easier to make; pouring is facilitated; and no side plates are needed. The metal can be poured at temperatures as high as 2750° F. Further improvement was made by forming the barrel core on a cast steel arbor with the same dry sand, the arbor being set up inside a cast iron

sleeve flush with the base of the core on the molding machine table.

The most satisfactory results as to density, structure, machinability, finish and service are obtained by using an iron that is varied in composition according to the cross-section of the cylinder, a typical analysis showing: 2.90-3.25% C, 1.75-2.25% Si, 0.90-1.00 Mn, less than 0.15 P, less than 0.15 S, 0.50 Ni. Coming from the cupola, the carbon is kept near 3.00%, silicon 1.80% and manganese near 1.00%. A knife-edge chill is taken from each ladle to indicate how close the iron is to the desired composition. Addition of 80% ferrosilicon and carbonaceous graphitizing material is made at the spout to adjust (soften) the iron for smaller cylinders. The metal temperature at the spout is always at least 2,800° F. VSP (1a)

Rolling Stainless

"Stainless Steel A National Asset." *Sheet Metal Ind.*, Vol. 14, Mar. 1940, pp. 257-260, 268. Description of sheet rolling at United Steel Co., England.

Induction-melted slabs are reheated in coke-oven gas-fired furnaces, broken down in 2-high mills, pickled, and ground if necessary. Finish hot rolling is carried out in 2-high stands, which have 32-in. diam. rolls with maximum length of 60 in.; the top rolls are positively driven in roughing. After the sheets are annealed in another coke oven gas-fired furnace at 1925°-2010° F., air-cooled and pickled, they are taken to the cold rolling plant, which is able to roll sheets 40 in. wide to as thin as 0.012 in.

The backing rolls (56-in. diam.) are forged chromium-vanadium steel (analysis not given) with chilled iron mantle (surface hardness 65-70 Shore) shrunk on. The working rolls (18 and 14 in. diam. x 48 in.) are chromium steel (analysis not given) with Shore hardness of 90-100. The roll temperature is controlled by circulating a cooling liquid through the hollow working rolls. The main drive is from a 500-h.p. variable-speed d.c. motor. The roll position is shown on a dial below each screw, as well as recorded in the substation. JZB (1a)

Insulation of Hot Blast Stoves

"Up-to-Date Insulation of Hot Blast Stoves." E. H. Younglove (Johns-Manville) *Blast Furnace Steel Plant*, Vol. 28, May 1940, pp. 461-463. Practical.

Economical thickness of thermally efficient insulating blocks over the checker area varies gradually from about 8½ in. at the shell top to about 1 in. at the stove bottom, while the thickness on the side combustion area is about 7½ in. over its full length. For structural reasons, insulation can be decreased in thickness in only a straight line. The amount of insulation at the top is made slightly less and lower down slightly greater than the economic ideal. In checkers, the insulation thickness usually tapers in a straight line from 7½ in. at top to 1 in. at bottom. On the combustion area and dome, the full economical thickness is used.

Insulating concrete may be employed in the bottom ring and around the hot-blast main connection. To permit use of the conventional ring wall, yet have decreasing insulation thickness, a steel shell can be constructed with its diameter decreasing from top to bottom. This may be done either by using metal rings of smaller diameter lapped within the rings above, or by butt welding plates to form a tapering shell. For existing stoves, proper insulation thicknesses may be used by increasing the ring wall thicknesses from top to bottom and decreasing the insulation thickness accordingly. Bases of stoves should be insulated to protect the bottom metal plate over its entire area, and additional insulation should be provided at the bottom of the combustion chamber.

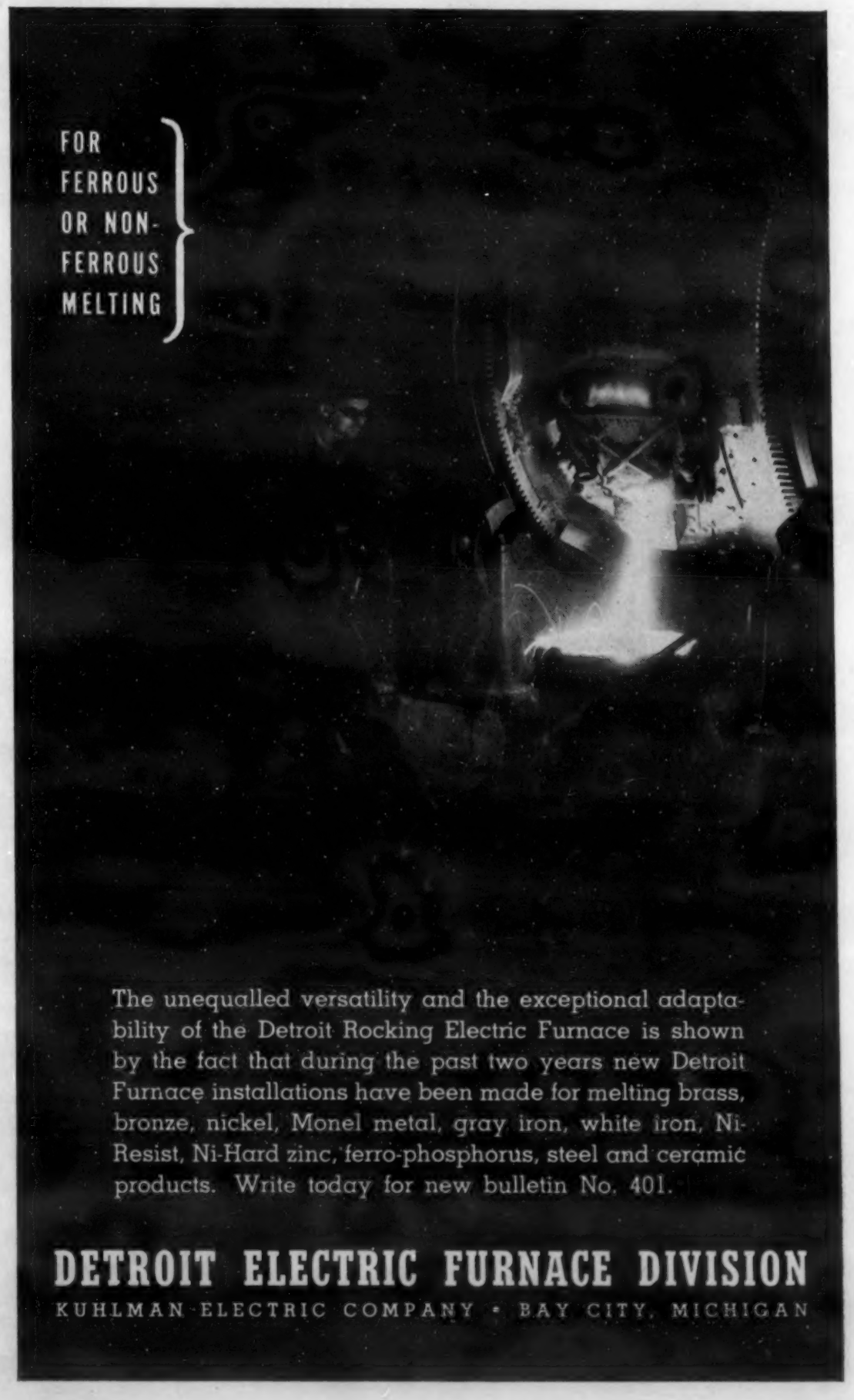
The total annual cost of heat loss and insulation is $1,444 for the above procedure, compared with $3,491 for bare stoves and $1,784 and $1,626 for the earlier practice. The insulation used is diatomaceous silica bonded with asbestos fiber. It is advisable to insulate also hot blast mains, bustle pipes, hot blast valves, blow pipes and cold-blast mains. Adequate insulation of stoves and equipment will reduce radiation losses 50-75%, raise the mean temperature of the stove wall, give higher blast temperature with a given amount of fuel, and provide more uniform and controllable furnace operation. MS (1a)

Anti-piping Compounds

"Anti-piping Compounds and Their Influence on Major Segregation in Steel Ingots." E. Gregory. *J. Iron Steel Inst.*, Adv. Copy, May, 1940. Original research.

The analyses of several anti-piping compounds are given. These show that they consist chiefly of mixtures of irreducible oxides and carbonaceous matter. One of these was used on several ingots, and segregation in these ingots and in untreated ingots was determined by examination of the top bloom.

When using the compound the final freezing of the liquid metal head in the ingot did not occur until 1 hr. after pouring and the liquid surface sunk 8 to 10 in. The use of the compound caused the



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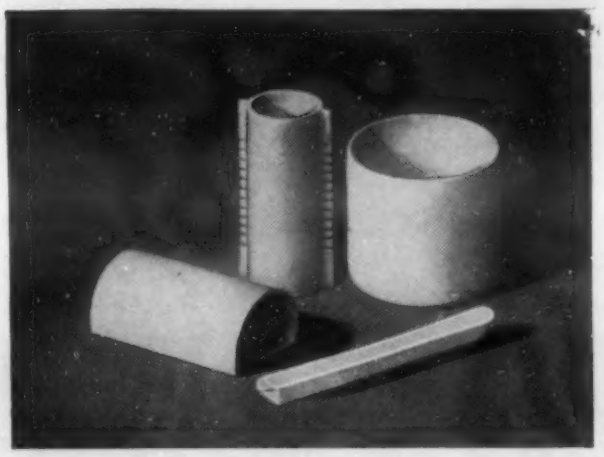

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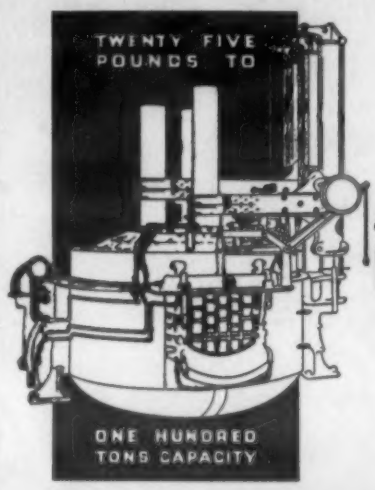

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heavily segregated portion of the ingot to rise toward the top. When the top of the freshly-poured ingot was covered with sheet asbestos and metal added to the hot top some time after pouring, the segregate also rose, but not so far as with the compound.

Cooling and freezing of the steel in an ingot is discussed and it is concluded that major segregation results from the separation of the homogeneous metal into two liquid phases, followed by an enrichment of one or even both of the liquid conjugates as freezing or solidification progresses. JLG (1a)

Electric Arc Furnaces

A Composite

At its meeting in April, the Electrochemical Society heard, among other things, three papers reviewing the current applications of the electric arc furnace for producing ingots, forgings and castings. Although each was fairly general, the three taken together offer a conveniently-read survey of the importance of the electric furnace for steel melting.

It is evident that the arc furnace is superior to the open-hearth furnace for the production of alloy steels, but it is seldom realized that electric furnaces are in actual competition with the open-hearth for ordinary carbon steels, says W. E. MOORE ("Present Status of the Electric Arc Furnace in Industry," *Trans. Electrochem. Soc.*, Vol. 77, 1940, Preprint No. 27, 7 pp.). Cheaper power supplies and better carbon electrodes are widely separated aids in the rapid development of electric melting. Fused mullite refractories, much used in recent years, have an advantage over others in the speed with which they can be cast and annealed.

The most important mechanical improvement in the electric furnace is the lift-swing-aside roof, which permits top charging of the furnace. This mechanism makes available the entire cubical capacity of the crucible, whereas in the side-door type furnace capacity is limited to the door level. Also, large or bulky scrap can be readily introduced and charging is more rapid.

Industry demands increasing amounts of special-purpose forgings, of which the electric furnace supplies a large tonnage. H. P. RASSBACH of the Midvale Co. ("Electric Furnace Alloy Steels for Forgings," *Ibid.*, Preprint No. 29, 11 pp.) cites operating flexibility, close chemical control, capacity flexibility, and steel cleanliness as important advantages of the electric furnace over the open-hearth for making forging steel.

The basic arc furnace produces less inclusions (deoxidation products) than the open-hearth, an advantage that easily overcomes for special forgings the objection of higher cost. Oxides in the metal bath are reduced at the slag metal interface and sulphur may be reduced to a low figure.

One disadvantage of the basic arc process is the greater susceptibility to "flakes" in high nickel-chromium alloys, through the absorption of hydrogen or nitrogen. Alloy steels made in the basic arc furnace contain more nitrogen than those made in the induction furnace or in the acid arc units.

For making steel castings in electric furnaces, acid practice is widely preferred, chiefly for economy reasons, according to F. A. MELMOTH of Detroit Steel Casting Co. ("The Electric Furnace in the Steel Foundry," *Ibid.*, Preprint No. 19, 6 pp.) As the acid lining does not remove sulphur or phosphorus from the steel, the melting stock must be low in these elements. Basic linings give lower slag losses and accurate recovery of alloy additions, but lower metal fluidity.

Of the 300 steel foundries in the United States, about 200 use electric melting furnaces, usually of the alternating 3-phase type. Steel so produced is capable of meeting any existing specifications, with the basic-process steel said to be unusually responsive to heat treatment, with the highest possible combination of strength and ductility. More extensive use of electric melting will depend on refractories developments, and improvement in the economic aspects of electric furnaces. AB (1a)

1b. Non-Ferrous

Casting Magnesium Alloys

"CAST MAGNESIUM ALLOYS." W. F. CHUBB. *Can. Metals Met. Inds.*, Vol. 3, Apr. 1940, pp. 100, 102. Review.

The importance of protection from oxidation in melting and from water in green sand molds is noted. The most essential requirement in magnesium foundry practice is the protection of alloys from oxidation. Protection may be provided through the use of inert atmospheres or suitable fluxes to cover the metal.

One type of flux used in England contains 68% magnesium chloride, 25% potassium chloride and varying percentages of sodium and calcium fluorides. In Germany a type of flux is used that thickens progressively and is introduced at the bottom of the metal. As the thickened flux is skimmed from the top of the melt fresh material is pushed to the bottom and on rising absorbs oxides from the metal. These oxides discolor the flux and the end of the refining operation is detected by the appearance of clear flux at the surface.

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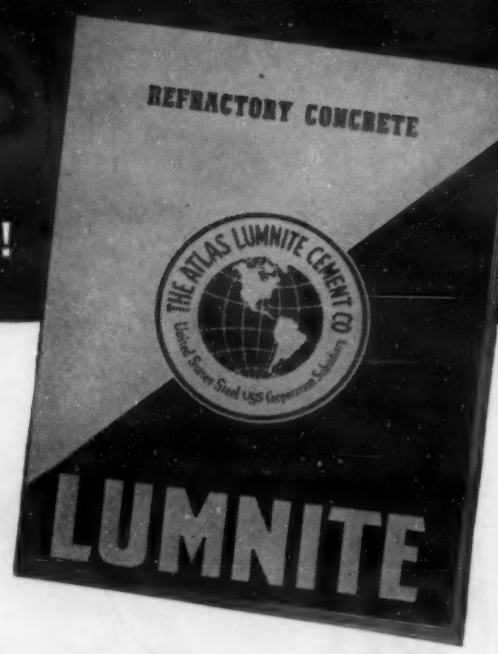

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Gas-fired, oil-fired and high-frequency induction furnaces may be used for magnesium melting. The flux employed usually amounts to about 3% of the charge and is mostly introduced at the bottom of the melt. Green sand molds containing certain agents to prevent action with the water present are used almost exclusively. The reaction between water and molten magnesium is prevented either by the formation of a neutral atmosphere next to the metal through the use of sulphur or similar substances or by the formation of a protective film on the surface of the metal by compounds such as ammonium fluoride or sodium silicofluoride. Some compounds such as boric acid and certain phosphates combine these two actions.

Magnesium alloys should be superheated to 1500° F. or more and cooled to 1400 or 1450° F. before pouring. Defects in castings and alloying elements and impurities are briefly considered. WHB (1b)

Melting Copper Alloys

"Melting Operations in the Non-Ferrous Industry." Frank Hudson. *Foundry Trade J.*, Vol. 62, Mar. 21, 1940, pp. 219-228; Mar. 28, 1940, pp. 242-244, 248. Practical review.

The author advises the use of slightly oxidizing atmospheres or the use of oxides within the metal (followed by deoxidation) for production of sound tin bronzes. This is contrary to older British practices of melting under so-called neutral or slightly reducing atmospheres.

The author's hypothesis is that hydrogen (present in many reducing atmospheres) is responsible for unsoundness. Work of Genders & Bailey (*Research Monograph 3, Brit. Non-Ferrous Metals Research Assoc.*) is referred to. Author considers that the high vapor pressure of higher-zinc alloys minimizes possibility of hydrogen absorption.

The incorporation of 1-2% black cupric oxide is a satisfactory addition to the initial charge, and 0.2-0.5% red cuprous oxide can be used in molten metal. Casting copper containing some oxide is more suitable than oxygen-free copper. Oxide additions should be followed by phosphorus deoxidation. Addition of a small percentage of zinc to tin bronzes improves their casting characteristics with no detriment to wear and corrosion resistant properties.

Actual analyses of furnace atmospheres are not given, and the recommended oxygen content of combustion gases is not specified. AIK+JWB (1b)

Aluminum Bronze Permanent Mold Castings

"Aluminum Bronze Gravity Die Casting." Arthur Street. *Engineering*. Vol. 149, Feb. 16, 1940, pp. 159-161; Feb. 23, 1940, pp. 190-191. Practical.

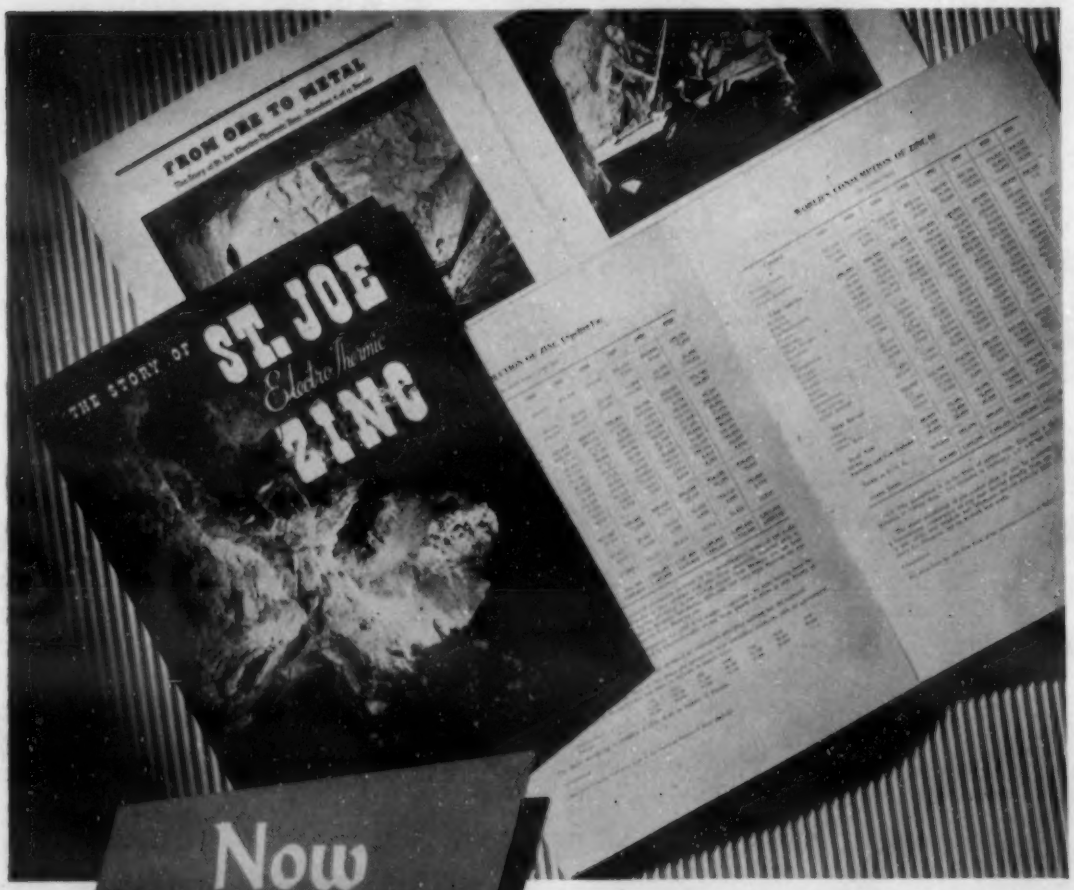
The commercial development of aluminum bronze can be credited to several factors. In the first place, Durville showed that occluded oxides in aluminum bronze could be avoided by casting in a non-turbulent manner. Then, the work of Carpenter, Edwards, Greenwood and Stockdale on the constitution of these alloys showed that these bronzes, and particularly the one with 10% Al, could be improved by heat treatment. Also, it was found that the addition of aluminum to copper improves corrosion resistance, particularly in sea water.

Aluminum bronzes were found to be much superior to ordinary carbon steels, and to compare favorably with high-grade stainless steels, with respect to corrosion-fatigue properties. By hot and cold rolling, forging, centrifugal casting or permanent mold casting, improved physical properties can be obtained. The 10%-aluminum bronze has strength equal to medium-carbon steel, high fatigue strength for a non-ferrous alloy, and resistance to corrosion equal to that of 80/20 copper-nickel. The important commercial alloys consist of copper containing up to 12% Al, but for castings alloys containing 8-11% Al are used.

All commercial aluminum bronzes have a narrow freezing range of only a few degrees. The addition of about 3% Fe to aluminum bronzes refines the grain and prevents self-annealing, and also increases the tensile strength by 4,000 to 5,000 lbs./in.^{2} and this rate of increase continues with iron additions up to 4%. The usual iron content for permanent mold castings is around 2% or less. Manganese is seldom used, but it has the same effect as iron. The same is true of nickel, but it is also claimed that nickel improves corrosion resistance. Considerable interest has been aroused in the possibilities of copper-aluminum-nickel alloys.

The permanent mold process for aluminum bronzes appears to have been developed between 1914 and 1918. The procedure is somewhat similar to that used in the ordinary foundry except that molds and cores are permanent and usually of a ferrous metal. The mold is generally made of cast iron, 3% Ni steel or special alloy cast iron, while cores are made from heat-resisting alloy steel. Often the molds are made of alloy cast iron, with segments of alloy steel inserted at specially important points.

In producing small castings, production



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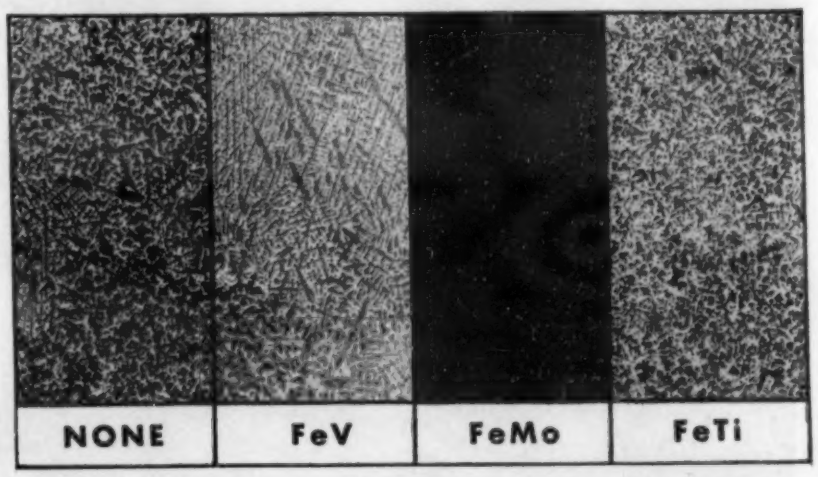

The macrographs above [from a report of the Research Inst. of the Skoda Works, Pilsen, presented as an exchange paper from the Czech. Tech. Foundry Ass'n, Sept. 1935] show the effects of different alloy additions on test ingots of .40 carbon steel made under identical conditions.

Of principal interest is the varying character of the dendritic crystals and the fact that each steel shows a well developed dendritic structure, except for the one treated with Ti where the dendrites are short, mostly nodules. This is the result of the influence of Titanium on primary crystallization which alters the mode of solidification, producing a larger number of centers of crystallization and a finer grain throughout the ingot.

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may average 30 to 40 castings/hr., while with large castings the figure may be less than 10. The best working temperature for the mold is between 500° and 750° F. Too high a temperature reduces mold life and may cause porosity of the castings. If a mold is used with care, it should last from 8,000 to 15,000 castings. Wear on the cores is indicated by hair cracks in the steel and by necking at the end of the core pin.

When permanent mold castings are cool, they are inspected for dimensional accuracy and surface appearance. Some machining may be required. On account of the high temperatures involved, the casting of threads is not attempted. The solidity of aluminum bronze permanent mold castings is the chief concern of the designer. To obtain highest soundness, the casting must be uniform in section and of such design that no portion will solidify before the rest. A useful working section is ⅛-in. When a part formerly sand cast is made by permanent mold casting, the section can often be reduced. VSP (1b)

Producing "Coalesced" Copper

"The Coalescence Process for Producing Semifabricated Oxygen-free Copper." John Tyssowski (Copper Deoxidation Corp.) *Metals Tech.*, Vol. 7, June 1940, T.P. 1217, 5 pp. Descriptive.

The coalescence process for copper was developed from the discovery in 1925 by H. H. Stout of Phelps Dodge Corp. that particles of pure copper heated in a closed hydrogen-filled tube seemingly stuck together. Crystal growth occurred *across* the particle boundaries, causing the several particles to become a single coalesced unit. In the modern patented process, by which this type of copper is now produced on a commercial scale, copper of cathode purity is produced in a semi-fabricated form from an extrusion press, by the application of 3,000 tons pressure on a 10-in. piston.

The problems that have had to be solved included the production of cathode copper in brittle, friable form; effecting complete union of the cathode particles; designing a press to make briquettes of the right porosity and density; methods for cleaning and preheating the cathode particles; and means of feeding the deoxidized cathode copper into an extrusion press without contamination from the air.

The process starts with the production of a suitable anode using standard practice except for the use of a mold wash (zinc oxide) with a melting point higher than that of copper, and which dissolves in the electrolyte during the production of brittle cathodes. Silica compounds are the principal deleterious materials to be eliminated.

The deposition of brittle cathodes depends on forming scattered crystal nuclei and impeding their mutual coherence as they build up. At the same time, the adherence of the nuclei and accretions to the re-usable blank on which they are deposited must be impeded. This is accomplished by omitting glue from the electrolyte and replacing it with a mixture of corn oil, castor oil, gasoline and carbon tetrachloride; an oil film is formed on the blank with just enough dielectric strength to cause the crystal starting points to be widely separated and to give an inherently brittle mass. Otherwise, the cathodes are made by standard American refinery practice.

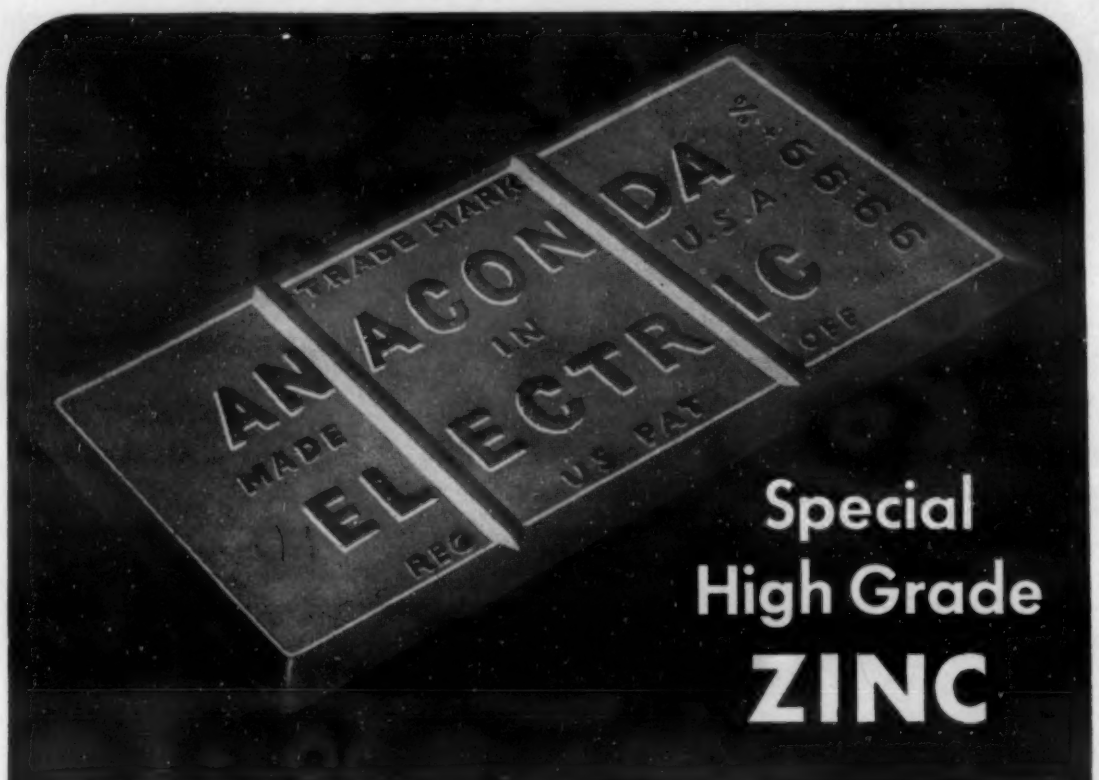
Because of the lower electrolyte resistance resulting from the omission of the glue and the solid instead of loop contact on the cathode starting sheets, power consumption is 75-85% of that for standard tough cathodes under similar operating conditions. Disadvantages in the new system are the higher labor costs and the higher silver and gold losses.

The cathode is shaken or knocked off and broken to the desired size and the depositing blanks re-used. For briquetting, the particles are compressed at about 20,000 lbs./in.^{2} on a baling-press plunger to 80-86% of the density of "solid" copper. The briquetted mass is porous but coherent and is permeable to the cleansing fluid later used.

The briquettes are then heated in a deoxidizing-atmosphere furnace at 1600°-1670° F.; the gas penetrates the pores, removes all traces of oxygen and reduces the arsenic, antimony and sulphur contents of the particles. The briquettes pass directly through a controlled atmosphere chamber to the extrusion press.

Extrusion pressures range from 30,000 lbs./in.^{2} for large cross-sections up to 75,000 for small. Coalescence—the development of a new grain structure between the copper particles—occurs, and the extruded product is of the highest purity and of uniform physical character. Rounds, rectangles and special shapes are regularly extruded. A bar with a maximum cross-sectional area of 20 in.^{2} can be extruded from a press handling a briquette 10 in. in diameter.

Coalesced copper is an oxygen-free copper. It has been called "sliverless" copper because its surface is superior to the usual hot-rolled copper. Its electrical conductivity is about 0.3% I.A.C.S. higher than electrolytic tough-pitch copper from the same blister copper source. The material has the capacity for almost unlimited cold-working without intermediate anneals. FPP (1b)



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Metal-Treating Uses of Propane

A Composite

Propane (C_3H_8) is one of the more important of the easily-liquefied light fractions obtained in the stabilization of gasoline. The commercial use of these liquefied petroleum gases is growing; 165,201,000 gallons were made in 1938. These data and a review of propane applications are given in one article digested herewith; the other reports on the suitability of propane for flame-hardening steel.

Propane, generally speaking, is an ideal gas for industrial use, according to CLARY, SHEELY and FYKE of Standard Oil Development Co. ("Industrial Uses of Propane," *Welding J., N. Y.*, Vol. 19, Mar. 1940, pp. 192-194). The use of propane as a cutting fuel for steel is steadily increasing due to its economy both as fuel and in handling costs. It is used for this purpose in steel mills, fabricating and manufacturing shops, railroad shops, scrap yards and for erection and dismantling work.

Commercial cuts having sharp corners, smooth sides and a drag sufficiently short to leave no firmly adhering slag, yet completely severing the plate at the end of the kerf are easily obtained with propane. The same cutting speeds can be used with propane as with other fuels. One of the newest fields in which propane offers exceptional possibilities is for metal-spraying. When operating continuously, savings as much as $0.50 per hr. per gun are obtained because of the relatively low cost of the fuel.

Considerable quantities of liquefied petroleum gases are used for industrial furnaces where heat treating or special treating processes are being carried out. The nonferrous metal-producing and fabricating industries use liquefied gases for bright annealing furnaces because of the exceptionally bright finish obtained. Propane is an ideal gas for carburizing. Experience has shown that liquefied petroleum gases are safe and economical as a fuel where a gas is desired.

The suitability of propane-acetylene mixtures for flame-hardening steel was studied by V. THÜRNAU ("Eignung von Propan und seinen Mischungen mit Azetylen für die autogene Oberflächenhärtung," *Autogene Metallbearbeit*, Vol. 33, May 1, 1940,

THERMOIL-GRANODINE FOOLS FRICTION

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pp. 105-115). All gas mixtures and combustion ratios studied were considerably inferior in performance to straight oxy-acetylene. The inefficiency of propane as a flame-hardening fuel is attributed not so much to its low ignition velocity or flame temperature as to its chemical nature, which requires an uneconomically large amount of oxygen for correct combustion. X (2)

Machinability Ratings

"Metal-Cutting Power Calculations." P. H. Miller. *Machinist*, Vol. 84, Mar. 2, 1940, pp. 23, 25; abstracted in *Nickel Bulletin*, Vol. 13, Apr. 1940, pp. 69-70. Investigation.

Formulas for power requirements for machining a variety of metals are presented. The relationship (if any) between the physical properties of the metal and the power required, and the relation of chip thickness and width to power requirements were determined. A range of representative plain and alloy steels, several grades of plain and alloy cast iron, and a few non-ferrous metals and alloys were studied.

The basic formula used is

Input h.p. = A + B

B = h.p. at each tool = DxFxSxC

A = friction h.p. lost in machine (25-30% of B for new machines and 35-40% of B for old). The constants are D = depth of cut, in.; F = feed, in.; S = cutting speed, ft./min.; C = power constants as listed in the Table, evidently based on correlation of data from many jobs.

In the article, each type of steel is subdivided according to different Brinell hardnesses available through carbon content and heat treatment modification, and "power constants" are given for each hard-

Power Constants for Machining Various Metals and Alloys

Material	Power Constant "C" for "Average Job"	Corresponding Brinell Hardness
Steel—S.A.E. 1010-1025	6.0	125-150
Steel—S.A.E. 1030-1055	8.0	175-200
Steel—S.A.E. 1060-1095	9.0	200-250
Steel—S.A.E. 1112-1120	6.0	150-175
Steel—S.A.E. X1314-X1340	5.0	150-175
Steel—S.A.E. T1330-T1350	9.0	200-250
Steel—S.A.E. 2015-2115	7.0	125-150
Steel—S.A.E. 2315-2335	7.5	200-250
Steel—S.A.E. 2340-2350	9.0	275-325
Steel—S.A.E. 2512-2515	8.0	200-250
Steel—S.A.E. 3115-3130	8.0	200-225
Steel—S.A.E. 3140-3450	9.0	250-300
Steel—S.A.E. 4130-4345	9.0	275-325
Steel—S.A.E. 4615-4820	9.0	275-325
Steel—S.A.E. 5120-5150	10.0	275-325
Steel—S.A.E. 52100	10.0	250-300
Steel—S.A.E. 6115-6140	9.0	225-275
Steel—S.A.E. 6145-6195	12.0	250-300
Plain cast iron	4.0	175-200
Alloy cast iron	4.0	150-175
Malleable iron	4.0	125-150
Cast steel	9.0	200-225
Brass—Hard	10.0	.....
Brass—Medium	6.0	.....
Brass—Soft	4.0	.....
Brass—Lead screw stock	4.0	.....
Bronze—Hard	10.0	.....
Bronze—Medium	6.0	.....
Bronze—Soft	4.0	.....
Aluminum—Cast	3.0	.....
Aluminum—Hard (rolled)	4.0	.....
Monel (rolled)	12.0	.....
Zinc Alloy Die Castings	3.0	.....

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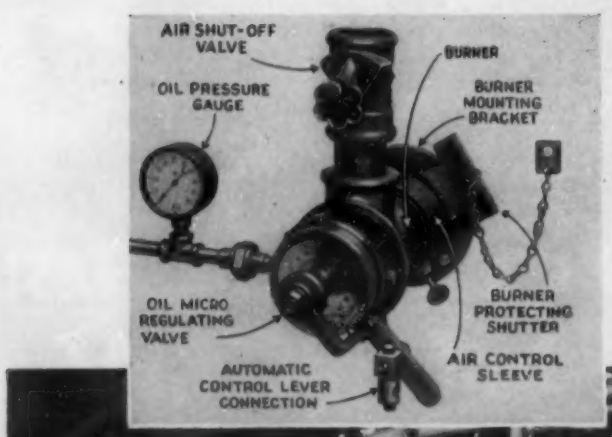

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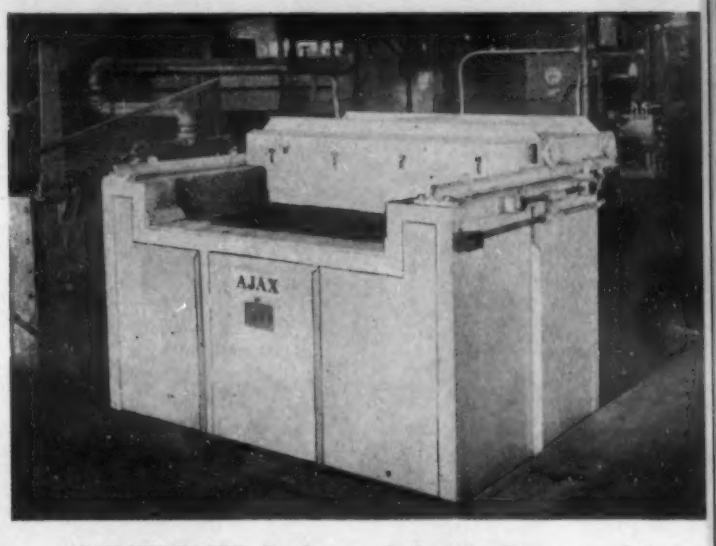

AJAX-HULTGREN Batch type Carburizing Furnace used for carburizing steel airplane parts and plate dies.

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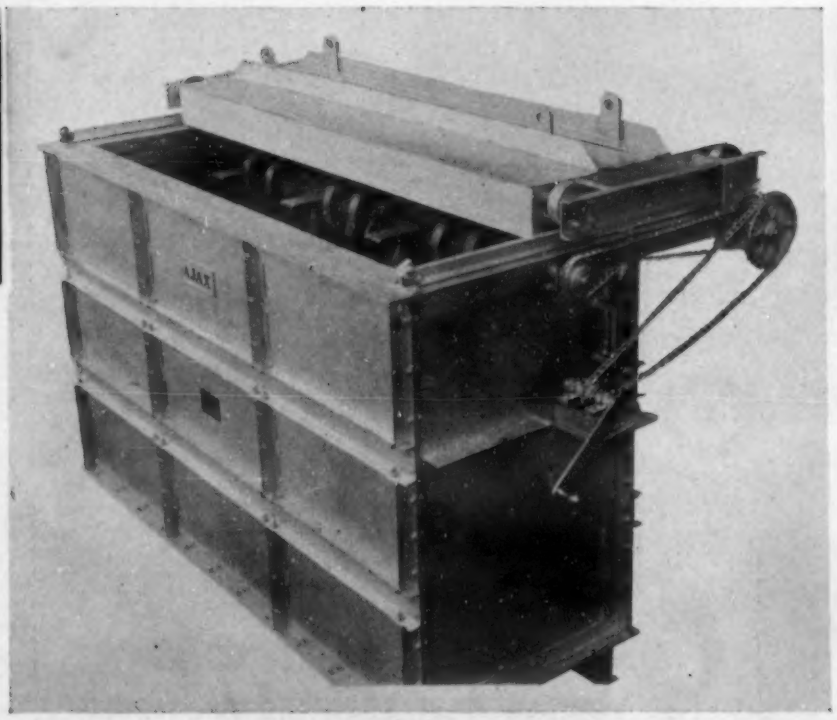

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ness range of each steel, based on the idea that for a given steel, the power required is approximately proportional to the Brinell hardness. [This digest gives only the "average job" constant and the steel hardness evidently characteristic of this average job. In view of the absence of (1) data on tool materials, and (2) information on the operation—milling, turning, drilling, etc.—publication of specific constants for narrow hardness ranges seems a meaningless refinement.—F.P.P.] For steels over 400 Brinell, the author recommends doubling the value of "C" given in the table.

Study of the relation between chip proportions and power showed that for chips more than 0.015 in. thick, power is almost directly proportional to chip width and thickness. For chip thicknesses below 0.015 in., the ratio of power to thickness is somewhat greater, but it was only with very thin chips that deviation from direct proportionality was found to be appreciable.

Typical check tests illustrate the agreement between horsepower values calculated by the above formula and those obtained in actual machining tests by the General Electric Co. FPP (2)

Infra-Red Radiation for Drying Coatings on Metals

THREE PAPERS IN A "CLINIC ON NEAR-INFRA-RED RAY HEATING," presented at the American Gas Association's Industrial Gas Sales Conference, Mar. 29, 1940. Survey.

Convection heating of drying, baking, Japanning and other low-temperature ovens much used in metal-finishing is being challenged by near-infra-red radiation heating methods. The former are gas-consuming units, the latter electric—hence the A.G.A.'s interest.

Near-infra-red ray heating is defined as "radiant heating from incandescent bodies at temperatures of 3500°-5000° F." by HALE A. CLARK of Michigan Consolidated Gas Co. Radiant rays are the most efficient medium for heat transfer—far more so than convection gases. The use of luminous flames for heating forging furnaces arises from recognition of this fact.

On the other hand, convection gases are much better heat *distributors*. Since the air in radiant drying ovens is not heated appreciably, it is necessary to locate the conveyor carrying the work so that each piece receives the energy directly. Uniformity may be improved through heat conduction from exposed to unexposed parts in contact, but even this is usually considered unsatisfactory as compared with the uniform heat distribution characteristic of convection.

A comparison between an infra-ray job handling 480 lbs./hr. and a gas oven handling 580 lbs./hr. shows the gas-heated unit to be much more economical. The gas job used 44 cents worth of gas for 1,000 lbs. of product, while the electric job used $1.84 worth of electricity per 1,000 lbs. of product. (Less heating energy was required by infra-ray heating, but the much higher unit cost of electric energy throws the comparison heavily in favor of gas.)

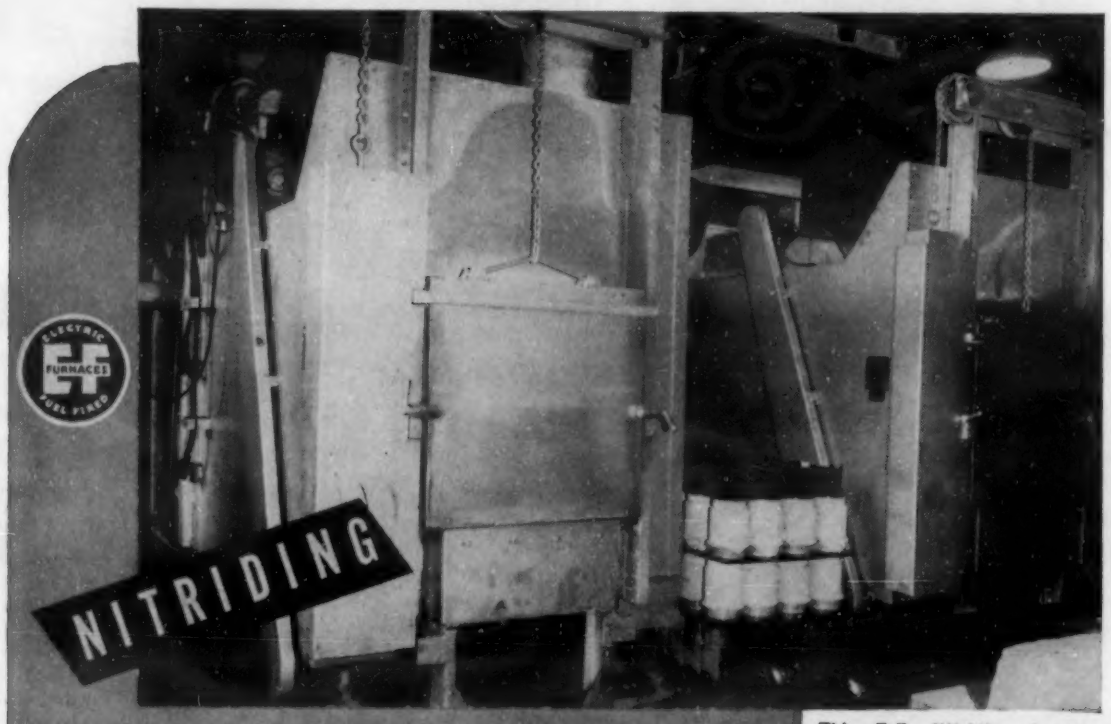
Also, when claims are made that a new baking device has appreciably shortened baking time, a possible change in the nature of the coating material should be investigated, for the type of finish has a powerful bearing on heat absorption characteristics. Also, the reduced baking time obtained with infra-red lamps is not due to some "catalytic action" associated with the radiation, but is simply the result of the work's reaching a higher temperature in a shorter time.

In drying finishes, as in heat treating steel, radiation and convection each has its place; combinations of the two methods also have real utility. Radiation is most valuable where the rays may be directed directly on relatively light sections of suitable shape. Convection has its place in baking light sections on whose surfaces radiant rays could not feasibly be directed.

A combination of radiation and convection is often better than convection alone. Equipment of this combined type made by his company (Selas Co.) was discussed by F. O. HESS. The difficulties of infra-red heating were demonstrated, particularly the inordinately careful control required to adjust for differences in form of work, color and finish variations, distance from lamps to work, cleanliness of reflectors, and "shadows" cast by conveyors, etc.

Claims that radiant heating cures the surface without bringing up the temperature of the body of the piece can be made equally well for recirculated air heating operating at high temperatures and high percentages of recirculation. Also, loadings can be much more compact with convected air because of the interstice-penetration feature of this type of heating.

An interesting development discussed by D. A. JACOBSON of Burdett Mfg. Co. is heating by gas-fired near-infra-red radiation devices. Actual installations, and the "beautifully-finished work" they turn out were described. Radiant gas burners, he said, can definitely out-manoeuvre any infra-red lamp now on the market, will permit the use of 98-cent-a-gallon finishes, and offer radically reduced production times from dip to shipping room. FPP (2)



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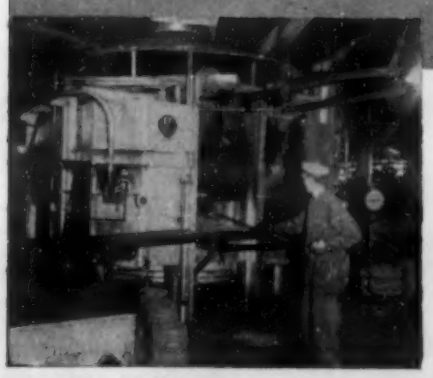

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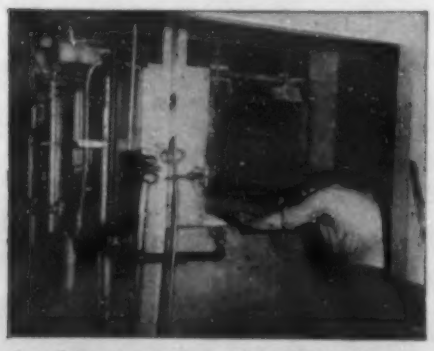

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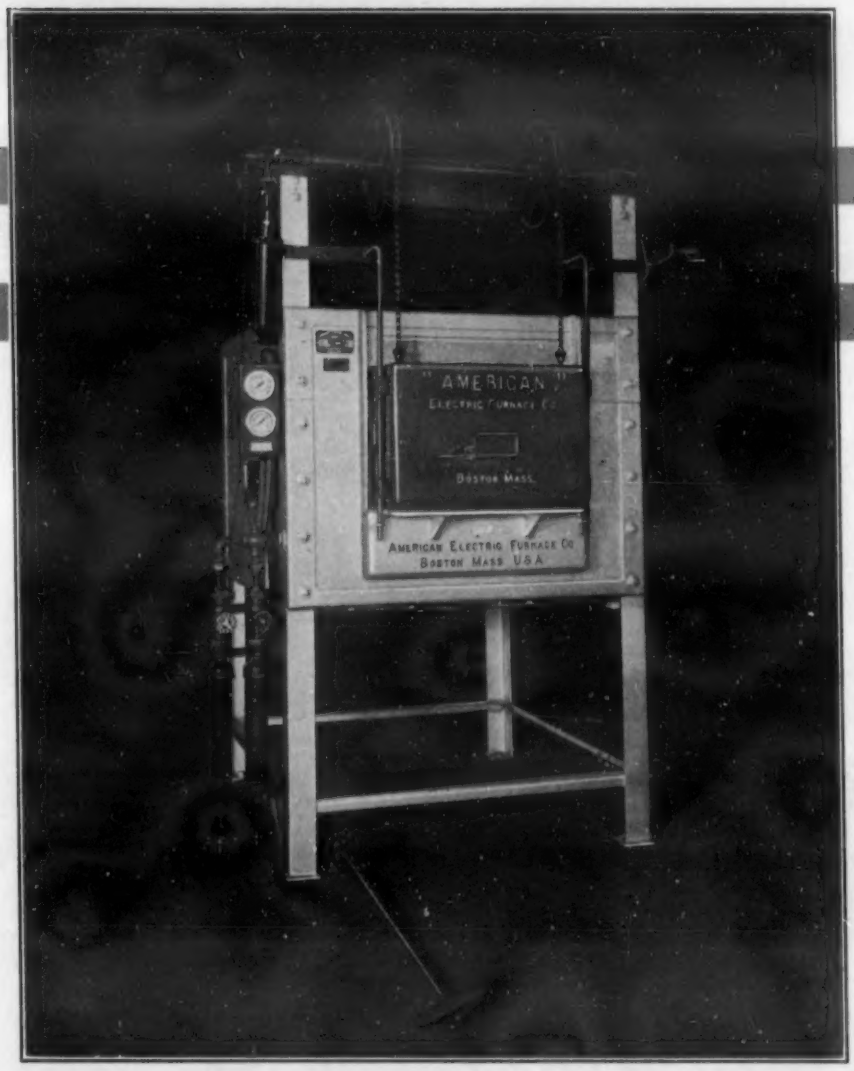

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Developments in Galvanizing —Hot-Dip and Electro

A Composite

Progress in both hot-dip galvanizing and electro-galvanizing has been unspectacular but steady. The extent to which one type of process is making inroads on the other is difficult to determine. Hot-dip galvanizers, under the pressure of competition from their "electro" cousins, are constantly improving the quality and economic status of their process; electro-galvanizers claim the imminence of commercial introduction of wide strip and sheet electrolytically galvanized. At present, the hot-dip process is used for most of the galvanized material made in this country.

Electro-Galvanizing

A broad review of the present status of electro-galvanizing is given by J. A. SINGMASTER of Singmaster & Breyer ("Progress in Electro-Galvanizing," Paper, *Am. Zinc Inst.*, Apr. 1940, 5 mimeographed pp.). The important electro-galvanizing processes are (1) the Meaker process, which uses a soluble High Grade zinc anode and a zinc sulphate bath; (2) the Coronizing process, which requires a preliminary electrodeposition of nickel, followed by electro-galvanizing, and finishing with a heat-treatment; (3) the Tainton process, which uses an insoluble anode and supplies the zinc to the bath in the form of a zinc sulphate solution, which in turn is obtained by dissolving zinc directly from roasted zinc ore; and (4) the Hubbell and Weisberg process, which also employs an insoluble anode and zinc ore directly, but dissolves the latter in ammonia and ammonium salts instead of sulphuric acid.

The Meaker and the Tainton processes are in widest commercial use, by far. The former has been improved by the use of zinc alloy anodes containing aluminum or mercury, or both, instead of pure zinc. The largest tonnage of zinc electro-galvanized by the Meaker process probably is applied to wire, but there are a host of other applications, mostly relatively small parts such as pipe and conduit fittings, bolts, nuts, screws, auto parts, washing machine parts.

The Bethlehem Steel Co. is the sole American producer of galvanized wire by the Tainton process. The product (Bethanized wire) goes largely into fencing for farm use, replacing the hot-dip galvanized wire formerly used. The process is now being adapted to sheets, and Bethanized sheets are now being made in a pilot plant. Two European plants employ the Tainton process, one galvanizing the wire used to hold the captive balloons employed for air defense, and the other working on the heavy wire or rods used in submarine-defense netting.

All of these methods are capable of producing adherent zinc coatings with excellent bending properties, of any commercial thickness on wire and narrow strip. The new Hubbell and Weisberg process, already applied to more than 100 tons of 10-in. wide strip, is said to yield a product with remarkable adherence for paint without any pretreatment. Early commercial application of some electro-galvanizing process to sheet is confidently expected.

Hot-Dip Galvanizing

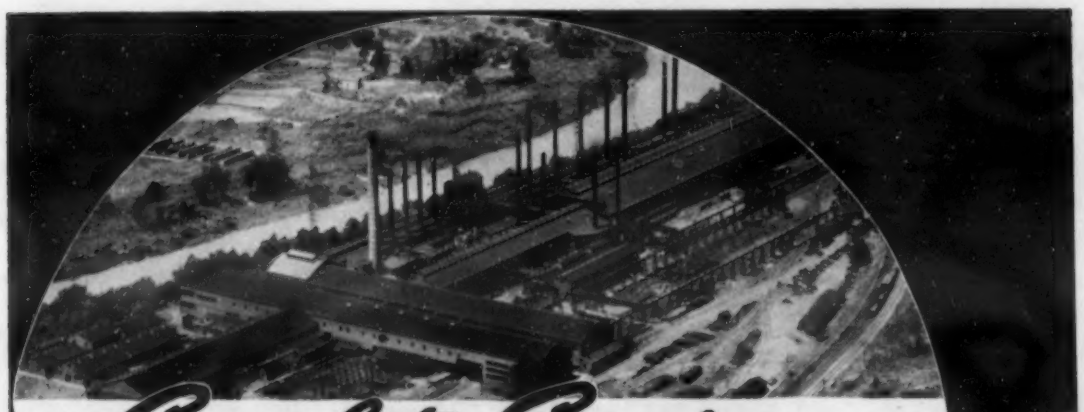
The galvanizing of sheets by the hot-dip process consumes over half of the slab zinc used for all galvanizing, reports J. L. SCHUELER of Continental Steel Corp. ("Developments in Hot-Dip Galvanizing," Paper, *Am. Zinc Inst.*, Apr. 1940, 8 mimeographed pp.). Other important applications of hot-dip are for galvanizing hardware and structural units, tubes, wire and wire cloth.

Zinc is a brittle metal, as-cast, and the hot-dip zinc coating is likewise brittle. Some of this brittleness may be eliminated by working the metal under controlled conditions within a narrow temperature range. However, in many cases of peeling or flaking of coatings, the real reason is insufficient adherence to the base metal rather than zinc brittleness.

The preparation of the steel base should involve (1) oil or grease removal by alkaline or solvent degreasing or by heating, (2) removal of scale or oxide by pickling, abrasive-blasting, molten salt baths, or electrolytic descaling, and (3) careful fluxing. There has been a marked trend to the continuous pickling of strip as part of stage 2, with much improved equipment, rubber tank lining, acid-proof brick, anodic pickling, high-speed apparatus, etc.

Although cleaning and fluxing are the heart of any hot galvanizing operation, set-practices for these stages are almost non-existent. Most development work is being carried out on the coating operation itself, with attention to furnace design, automatic temperature control, sheet-handling equipment and metallurgical control. Radiant tube heating has been proposed; firing is being done more and more above the dross-line to avoid direct flame impingement on the pot; recirculation of combustion products is in use.

In one process the pot is designed to allow dross to be moved out of the path of the sheet at the exit rolls. The production of uniform spangles is accomplished in one method by passing the sheet between



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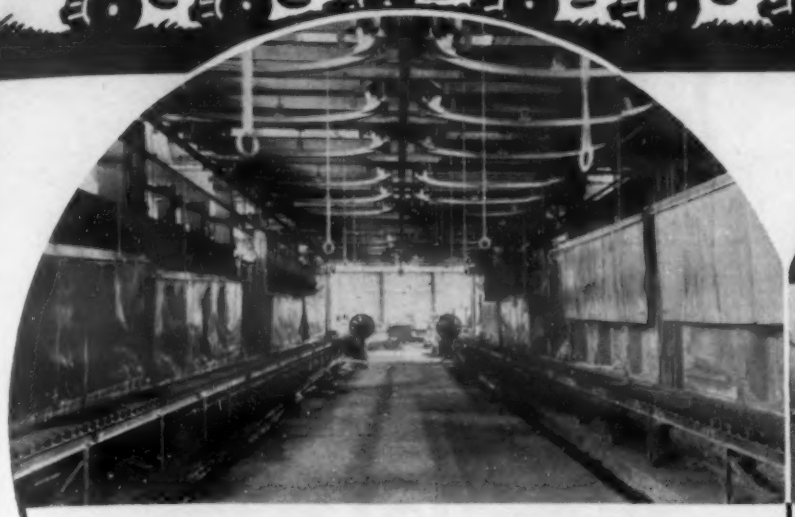

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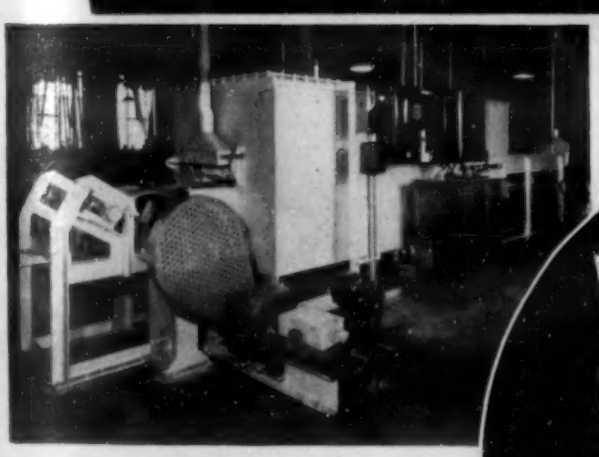

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knobbed rolls just beyond the exit rolls, with careful control of temperature, speed and bath composition. Faster cooling of sheets has permitted higher coating speeds. And galvanizers are becoming increasingly concerned with the composition of the steel base, its heat treatment and other metallurgical engineering data needed for steady improvement.

Another method of producing a highly uniform-spangled deposit is by diffusing a small percentage of aluminum throughout a zinc bath. The complex factors involved in spangle control by this method are discussed by W. G. IMHOFF of Am. Hot Dip Galvanizers' Assoc. ("Complicated Factors Accompany Use of Aluminum in Galvanizing," *Steel*, Vol. 106, Apr. 29, 1940, pp. 54-55). The aluminum is depleted very rapidly from the bath by oxidation, particularly as the iron content of the bath rises. Too little aluminum may result in badly-frosted areas, too much in poor fluxing, sluggish melting and low coating-quality.

The general features of some of the more technical aspects of hot-dip galvanizing are reviewed by H. R. STANLEY of the Univ. of Missouri ("Hot-Dip Galvanizing—A Review of the Process," *Metal Progress*, Vol. 37, Apr. 1940, pp. 431-435). Among the important developments cited are New Jersey Zinc Co.'s "Cronak" cleaning process, which comprises solvent-degreasing, cleaning in dilute hydrochloric acid, dipping in a dichromate solution, rinsing and rapid, low-temperature drying.

Another is the Armco Zinc-grip process for continuous galvanizing of low-carbon steel or ingot iron strip (a difficult job by conventional practice), which aims at an oxide-free surface prior to galvanizing. To obtain this, a thin layer of oxide is first formed and then reduced in a hydrogen atmosphere at 1100° F. X (2)

Welding and the War

"REVIEW OF WARTIME ACTIVITIES OF BRITISH WELDING INDUSTRY." JOHN S. TREVOR. *Welding Engr.*, Vol. 25, May 1940, pp. 23-26. General discussion.

In contrast with the war of 1914-1918, the present conflict finds welding fully developed. Generous use is being made of it in naval shipbuilding, the construction and repair of tanks, army truck bodies, etc., for civil defense purposes, and in the building of new armament factories and bridges of great strategic value.

The Institute of Welding in Great Britain, prominent welding concerns, and government training centers are busy training welding supervisors and operators. A move is also being made to use women in the welding industries for light work, particularly light gas welding. Of considerable interest also is the formation of a welding company of the Royal Engineers, recruited largely from members of the Institute of Welding. This company will include approximately 8 officers and 300 men. Through their activities tanks will be repaired only a short way behind the front line and damage to armored cars, convoy lorries and artillery made good on the spot.

One of the most important applications of welding in Great Britain's war effort is in her naval shipyards. Naval architects are fully cognizant of the efficiency of welding for steel structures, and of its ability to save considerable steel and thus permit the use of a large proportion of a ship's displacement for purely military items. The naval warfare so far has provided evidence that the all-welded hull can take as much if not more punishment than the former riveted structure. Examination of the battered German pocket battleship *Graf Spee* in Montevideo harbor has provided unmistakable evidence that the welded joints were intact and that the ship was by no means irreparably damaged.

One of the greatest advances made in the practice of welding in British warship construction was in the building of the aircraft carrier *Ark Royal* at Birkenhead. This ship is 800 ft. long overall, has 9 decks and is reputed to be 75% arc-welded. One of the most interesting uses of welding is in building of industrial air raid shelters. Welding is also used in the construction of bomb-proof shelters able to keep out 600-lb. semi-armor-piercing bombs. CEJ (2)

D.C. vs. A.C. Arc Welding

"QUALITY OF WELDS EFFECTED WITH D.C. AND A.C." S. G. P. DE LANGE. *Welding Ind.*, Feb. 1940, pp. 7-9; abstracted in *Welding Lit. Review*, Vol. 2, May 1940, pp. 219-220. Investigation.

Tests were carried out to compare the quality of welds made with an alternating current arc and with a direct current arc. Test welds were made in heavy plates about 6 ft. x 3 ft. x 1⅜ in. thick, the joint being a single U butt weld with either 20° or 10° angle bevelling. The completed welds were examined by X-rays and mechanical properties determined.

The quality of the welds made with a.c. and with d.c., using thickly coated high quality electrodes, is equal as regards tightness, purity and mechanical properties. It is only in very narrow welds that welding

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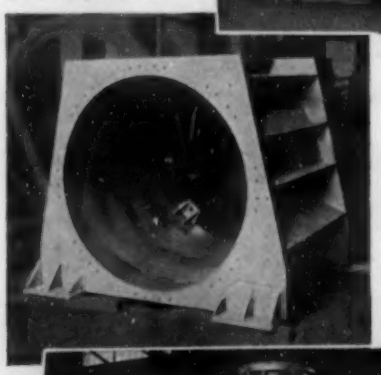

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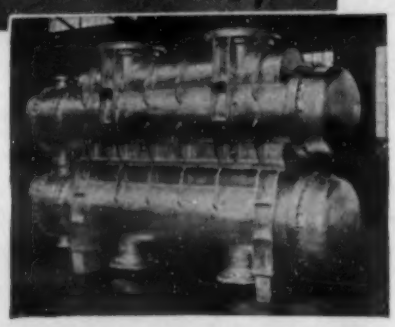

Fillets in these Murex-welded petroleum condensers, built by Ross Heater Co., Buffalo, are typical of Fillex welds.

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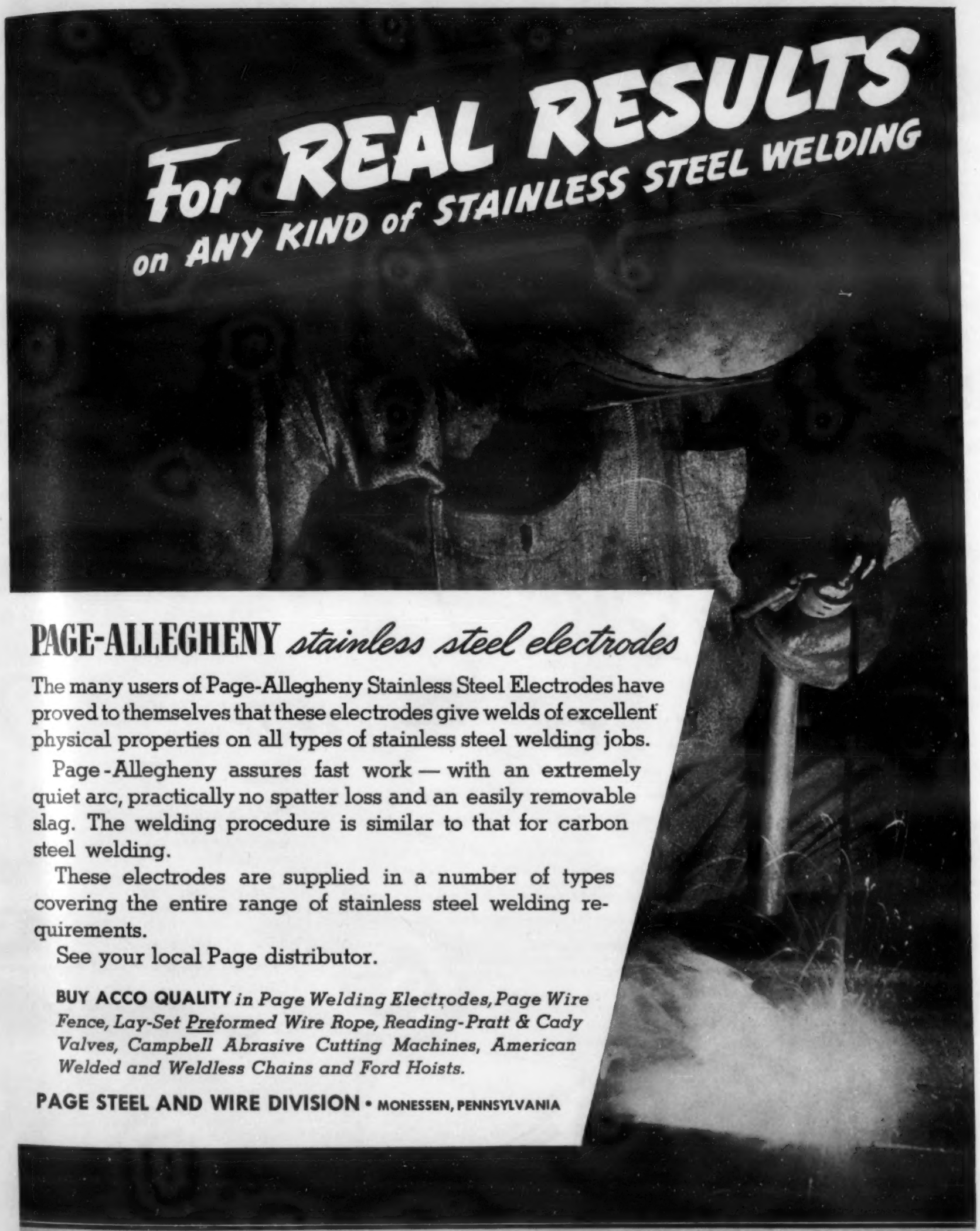

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Page-Allegheny assures fast work — with an extremely quiet arc, practically no spatter loss and an easily removable slag. The welding procedure is similar to that for carbon steel welding.

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faults may occur due to the deviations of the arc in the case of direct current.

Welding with d.c. is recommended only for difficult work such as welding sheet metal, the various kinds of stainless steel, aluminum, bronze, etc. For heavier work, d.c. and a.c. give identical results. FPP (2)

2a. Ferrous

Heat Treatment of Rails

"No Shatter Cracks in Rail—No Transverse Fissures." J. F. Woschitz (Inland Steel Co.) *Railway Age*, Vol. 108, Apr. 13, 1940, pp. 668-670. Descriptive review.

The principal changes and improvements in the manufacture of rails in this country during the last 20 yrs. have been in the finishing treatment afforded them. Modern rails, in addition, have higher carbon contents. Specifications and rail sections have been standardized. In Europe rails are produced with a high-strength steel in the head and a lower-strength steel in the remainder.

The principal commercial rail treatments developed in recent years include controlled cooling, Brunorizing or normalizing, end-hardening of rails, and welding of rails into long sections. Controlled cooling promises to bring about the elimination of transverse fissures in track. The Mackie process in Canada, the Sandberg process in Europe, and certain in-between methods in America are standard procedures for controlled cooling. Brunorizing gives a finer-grained and tougher steel with better low-temperature impact resistance than ordinary rails. End-hardening reduces end-batter and cuts down maintenance cost.

Only in the last 5 yrs. has proof been found of the old theory that transverse fissures originate in shatter cracks and that the latter can be alleviated or eliminated by controlled or retarded cooling of rails from their rolling temperature. More than a million tons of controlled-cooled rails have been in service in this country during the last 5 yrs. without the occurrence of a single transverse fissure.

The Sandberg method is based on the theory that shatter cracks form in cooling through the 935°-650° F. range, which corresponds to the peak tensile strength of rail steel. After the rails leave the hot saw they are allowed to cool in air to just above 935° F., then charged into an enclosure in which rail temperatures are equalized. Cooling of the rails is then retarded down to 660° F., after which normal air-cooling may be applied.

The Mackie method is based on the theory that the shatter cracks form in the "blue brittle" range—400°-575° F. Controlled cooling, however, starts above 660° F. and is applied so that at least 15 hrs. is required for the rails to cool to 175° F. Both the Sandberg and Mackie processes have been remarkably successful in eliminating shatter cracks.

The controlled-cooling practice proposed by the American Railway Engineering Assoc., permits cooling in the ranges of both the Sandberg and Mackie processes. Rails are charged into boxes between 725° and 1,000° F. and are cooled at such a rate that they reach 300° F. in 15 hrs. or more. At Inland, 16 controlled-cooling boxes made of corrugated galvanized sheets and provided with insulated covers and an insulated bottom, are employed. Gary works of Carnegie-Illinois Steel Corp. is successfully using insulated and covered gondola railroad cars as controlled-cooling enclosures.

Inland's controlled cooling practice has completely eliminated shatter cracks or thermal cracks. When shatter cracks have been found in a heat subjected to special tests, they have always been in hot-bed-cooled rails. Generally speaking, in addition to their all-important freedom from shatter cracks, controlled-cooled rails are a little better physically than hot-bed-cooled rails, and should have as good wear resistance in track under service conditions. (2a)

Electric Stress-Relief Furnaces

"Stress-Relief by Electric Furnace Treatment." M. V. Healey & F. H. Miller (Gen. Elec. Co.) *Gen. Elec. Rev.*, Vol. 43, Apr. 1940, pp. 170-173. Descriptive.

Dimensional stability in large fabricated or cast structures is achieved by "stress-relieving." If properly applied, this process relieves the locked-up internal stress caused by unequal cooling or hindered contraction not only of cast or forged parts but of large welded structures.

In low-carbon steel, which makes up the larger part of weldments and castings, a maximum temperature of 1200° F. maintained from 4 to 6 hrs. (1 hr./in. of maximum-section-thickness) will be sufficient. A maximum heating rate of 90° F./hr. should be employed if cracking and heating-up distortion are to be avoided. Cooling from the stress-relief temperature is perhaps the most important part of the cycle. Furnaces must be large and provide positive and dependable temperature control throughout the entire treatment.

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Electric furnaces are particularly adaptable to this work. One such furnace used in General Electric's Schenectady plant is a 2,000 kw unit capable of handling loads 27 ft. long, 13 ft. high and 17 ft. wide. The loads average between 80 and 100 tons each. The furnace is provided with automatic zone heat control, with which the most exacting temperature requirements can be met.

Unless some means is provided for accelerating the dissipation of heat during the cooling stage—which would normally proceed very slowly in a well-insulated furnace—cycles as long as 100 hrs. may result. Therefore, the furnace described contains a forced-cooling system comprising a centrifugal fan capable of furnishing 4,500 ft.^{3} of air/min. at 4 in. of water pressure. The air passes through the car bottom and over the heating units. This auxiliary cooling system resulted in an increase in cooling rate from 11° F./hr. to 42° F./hr., and a consequent 60% reduction in overall stress-relief time for heavy loads. A typical heavy-load cycle is now only 40 hrs. long. (2a)

Piston Ring Coatings

"Piston Ring Coatings and Their Effect on Ring and Bore Wear." Max M. Roensch (Chrysler Corp.) *S.A.E. Journal*, Vol. 46, May 1940, Trans. pp. 221-228. Investigation.

Piston-ring scuffing occurs most frequently during the break-in period. The leading ring companies have developed coatings that aid in preventing scuffing. Nearly all automobile companies use coated rings. The chemical coatings employed are known as "Ferrox," "Granoseal," "Graphitox" and "Grafotox," and "Surfide." A familiar metallic coating is electrolytically deposited tin.

Ferrox is a magnetic iron oxide coating produced by oxidizing machined iron surfaces to a predetermined depth in an enclosed chamber heated to about 1000° F. in the presence of a gaseous oxidizing agent. The ferrox film consists of 2 layers, each about 0.00015-0.002 in. thick. In normal automotive work, the optimum total thickness is 0.0003 in. The initial layer of the film as it is deposited is well rooted into every microscopic crevice of the parent iron so that the thinner the film, the more adherent it becomes.

The Granoseal coating consists of an iron phosphate with a high percentage of manganese phosphate. It is produced by immersing the part in an aqueous solution of phosphoric acid saturated with iron and manganese phosphates at 210° F. The coating thickness is 0.0002-0.0003 in. Graphitox and Grafotox coating, also known commercially as Bonderite D, consists of zinc-iron phosphate produced in a bath containing phosphoric acid and zinc phosphate. It is always used with an activator. After coating, the rings are dipped in an emulsion of soluble oil containing colloidal graphite.

The Surfide coating is produced by treating the cleaned rings in a bath of sodium hydrate, sulphur and water, which removes certain portions of the metal and produces a somewhat porous surface covered with a film of iron sulphide (FeS). The film thickness is about 0.0001 in. or less. The altinizing process consists of electro-plating tin on rings in a sodium stannate bath at 160° F. The surface must be cleaned chemically and acid-etched before plating. The coating thickness is 0.0002-0.0003 in.

The oxide coating is hard, brittle and mildly abrasive so that the ring itself can polish off the excess cast iron of the bore and the material that is scuffed off the ring can aid in further finishing the surfaces. A softer outer layer permits rapid seating and harder layer slows down wear to a greatly reduced rate. Phosphate coatings are softer than the raw iron, which gives them a quick initial seating. However, the individual crystals are harder than the iron so that, if they scuff off, they may aid in lapping-in the parts. These coatings absorb and retain considerable amounts of oil. The effectiveness of the Surfide coating is due to removal of some of the easily-welded constituents in the ring surface, microscopic oil reservoirs created by etching of surface, and extreme-pressure characteristics of the iron-sulphide coating, which prevents metal-to-metal contact.

The tin coating is the softest of all, permits rapid seating, and distributes the load over the ring face readily. It is possible that tin itself might be considered a lubricant when metal-to-metal contact occurs. Tin will also retain considerable oil.

Accelerated wear tests on newly finished surfaces with coated compression rings on half the pistons, uncoated compression rings on the other half, and all oil rings uncoated, showed that wear of the treated rings was half that of the untreated rings. Though uncoated, wear of oil rings run below treated rings was also reduced about the same amount. Tests with both compression and oil rings coated indicated that wear was practically eliminated.

Road tests with coated and uncoated rings showed a 25% reduction in wear of rings attributed to coating. Field experience with coated rings shows a marked reduction in oil consumption complaints from ring-scuffing during break-in period. There has been no indication that increased bore wear accompanies the reduction in ring wear. Tests of chemical coatings applied to entire cylinder surface indicate that proper coating properly applied will result in reduced wear and longer life of rings and cylinders. MS (2a)

2b. Non-Ferrous

Heat Treating Aluminum Alloys

A Composite

Aluminum and its alloys loom ever larger on the metallurgical engineering horizon as aircraft production reaches constantly higher levels. The heat-treated alloys, particularly, offer the aircraft engineer an extremely attractive strength/weight ratio. Recent articles have discussed the effects of plastic deformation, of composition, and of aging temperature on the properties of heat-treated aluminum-copper-magnesium and other aluminum-base alloys.

Work done in the past has indicated that neither time at solution-annealing temperature nor amount of prior deformation had an appreciable effect on the mechanical properties of duralumin-type alloys after heat treatment. This was checked by H. Unckel ("Versuche zum Einfluss von Wärmebehandlung und Verformung auf die Eigenschaften von einigen aushartbaren Aluminiumlegierungen," *Metallwirtschaft*, Vol. 19, Jan. 19, 1940, pp. 37-44), who ascertained that cold drawing will at first cause a considerable drop in the tensile strength in the heat-treated condition as compared with the heat-treated properties of the original extruded stock, but that on further drawing the strength increases. X-ray diffraction studies indicated that the initial decrease in strength obtained on cold drawing extruded stock was caused by a change in preferred orientation while the increase in properties with further cold drawing results from grain refinement.

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Cold working does have a definite effect on the properties of room-temperature-aged duralumin, however. H. KOSTRON ("Ueber das Zusammenwirken von Kaltverformung und Raumtemperaturaushartung bei Aluminium-Kupfer-Magnesium-Legierungen," *Z. Metallkunde*, Vol. 31, Nov. 1939, pp. 329-334) shows how plastic deformation accelerates room-temperature-aging, but increasing plastic deformation combined with aging results in a lower (total) maximum hardness obtainable. Plastic deformation before room-temperature aging causes a higher final hardness than in undeformed material, but the higher the amount of this cold-working, the lower the ultimate hardness. Duralumin plastically deformed before aging is more completely aged than material merely quenched before aging.

All these problems involving cold work followed by age-hardening must include the factor of recrystallization or simple softening above certain temperatures. Using aluminum - copper - magnesium and aluminum-magnesium alloys, H. BOHNER & E. MOHR ("Rekristallisations untersuchungen an Al- Mg- und Al-Cu-Mg-Legierungen im kritischen Verformungsbereich," *Aluminium*, Vol. 22, Feb. 1940, pp. 57-58) studied the effects of composition, degree of deformation, annealing temperatures and time, and initial grain size on properties and structure. Physical property changes were noted with rising temperatures before there was any change in structure. Definite dependence of the degree of critical deformation on any specific magnitude of cold-deformation before annealing, or on a definite residual stress after annealing, could not be established.

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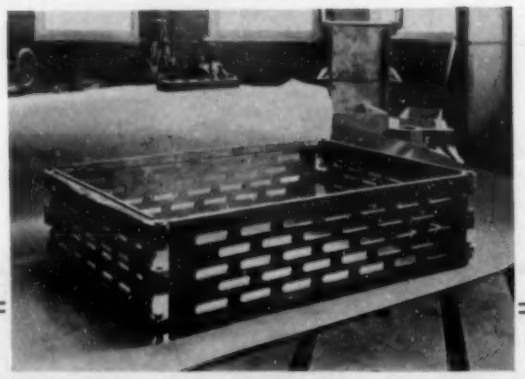

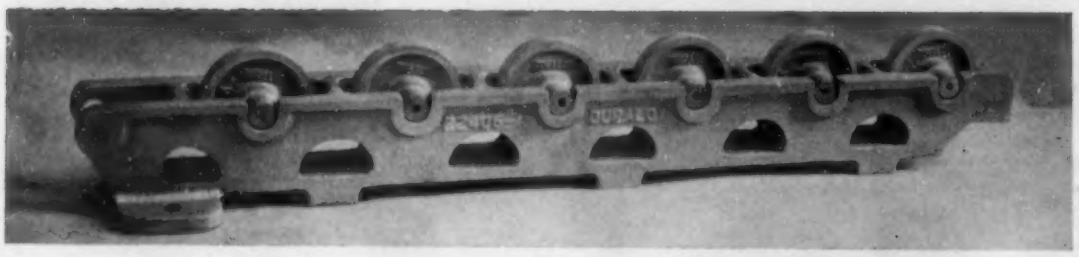

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If you are in need of chrome-iron or chrome-nickel castings for meeting problems of high temperature, corrosion, or abrasion, keep in mind that Duraloy is definitely among the leaders in this special founding business, having been making static castings since 1922 and centrifugal castings since 1931. Both dates are pioneering dates. Keep in mind, too, that it requires skill, experience, and modern equipment to produce sound high alloy castings.

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The effect of iron content on the age-hardening of super-duralumin (24ST) was investigated by H. Nishimura ("An Investigation of Super-Duralumin—the Effect of Iron," *Nippon Kinzoku Gakkai-Si*, Vol. 3, Nov. 1939, pp. 420-424; in Japanese). Increase in iron content suppressed age hardening in alloys quenched at 925° F. and aged either at room temperature or 125°-300° F.

Reverting to straight aluminum-magnesium alloys, G. SIEBEL & H. VOSSKÜHLER ("Bestimmung der Löslichkeit von Magnesium in Aluminium," *Z. Metallkunde*, Vol. 31, Dec. 1939, pp. 359-362) studied the solubility of magnesium in aluminum by determining lattice constants and electrical resistance. They found a greater solubility at elevated temperatures and a smaller at low temperatures than heretofore assumed. Maximum concentrations of the alpha-phase were 1.9% Mg at 100° C., 17.4% Mg at 449° C. (maximum solubility) and 0.3% at 650° C. X (2b)

Deep Drawing Aluminum Alloys

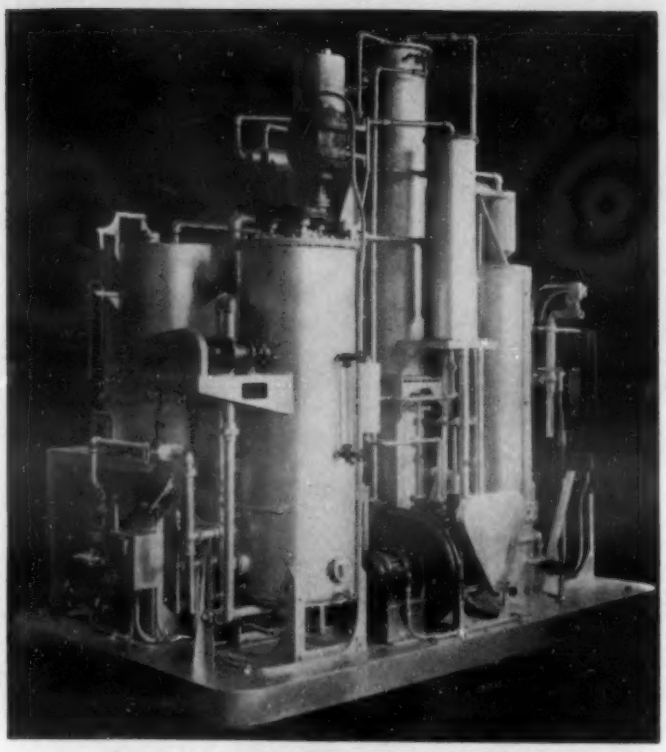
DEFORMATION PHENOMENA IN DEEP DRAWING AND SUITABILITY OF ALUMINUM ALLOYS FOR DEEP DRAWING WORK ("Verformungsvorgänge beim Tiefziehen und die Eignung von Aluminum-Legierungen für Tiefzieharbeiten) H. GUTH & G. SCHMIDTKE. *Metallwirtschaft*, Vol. 19, Mar. 15, 1940, pp. 193-200. Investigation.

The report covers drawing tests on aluminum, aluminum-manganese, aluminum-silicon, aluminum-magnesium, aluminum-magnesium-manganese, and aluminum-copper-magnesium sheet alloys on a Wazau deep drawing machine. The influence of hold-down pressure, die and punch radius, and drawability of the various alloys was studied. Experiments on hold-down pressure indicated that the minimum hold-down pressure with which there is no wrinkling is the most satisfactory. This amounts to about 100 lbs./in.^{2} for quenched aluminum-copper-magnesium sheet and was used throughout this work.

Sheet surface, as rolled or polished, had little effect on the drawing stress required with equal hold-down pressure. The blank hold pressure is roughly 0.1% of the drawing stress for aluminum-copper-magnesium alloys, 0.21% for aluminum-manganese alloys, and 0.17% for the aluminum-silicon alloys. From the slope of the drawing stress vs. hold-down pressure curves, the coefficient of friction of the aluminum - copper - magnesium sheet was roughly determined as 0.2 and of aluminum as 0.14.

In order to fulfill the conditions for pure deep drawing, it was found necessary to have the annulus between die and punch 1.4 times the thickness of the sheet. Experiments with varying die radius indicated that it was only possible to draw without tearing if the radius is greater than twice the sheet thickness. With increasing die radius, the drawing pressure drops but scoring increases to such an extent that the die radius should not be more than 4 or 5 times the thickness of the sheet. Punch radius is of little influence so long as the radius is equal to or greater than 3 times the sheet thickness.

Tests on drawability, wherein drawability is defined as the ratio of blank diameter to punch diameter, indicated that the aluminum - copper - magnesium sheet in the quenched state had better drawability than the pure aluminum sheet. Drawing stress was of course considerably higher on the aluminum-copper-magnesium alloys. Drawability was measured on a wide range of aluminum alloys and tempers. GA (2b)



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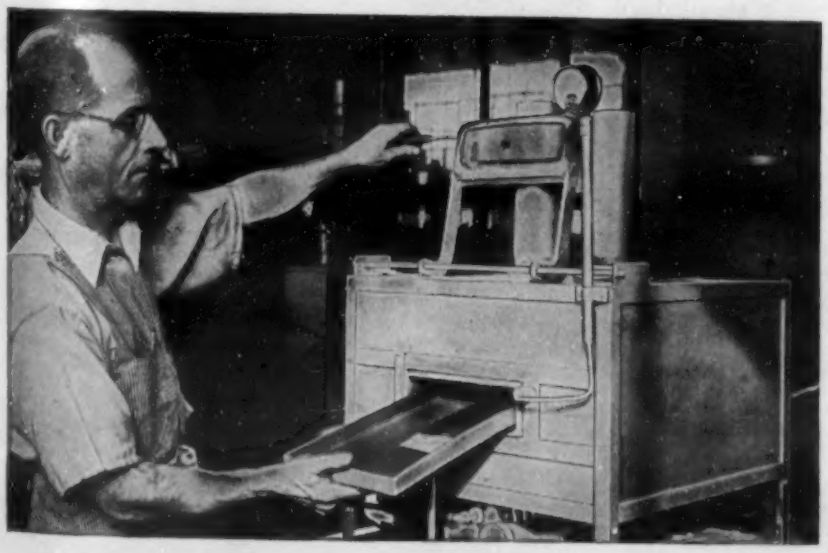

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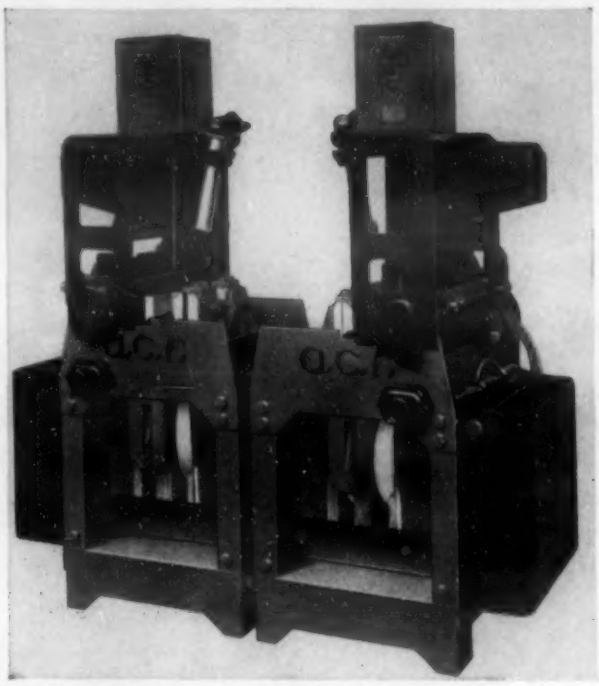

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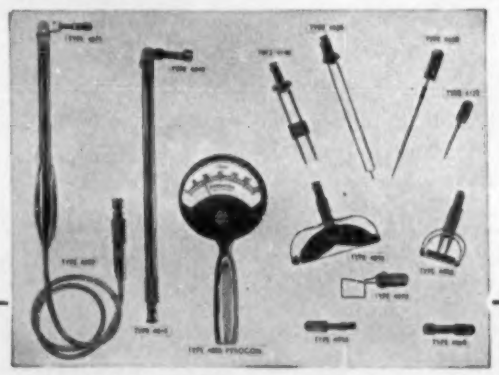

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3 Properties and Applications

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Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

Diffusion

A Composite

Diffusion phenomena are important factors in many metal-treating and fabricating operations and in various types of service. In carburizing, age-hardening, powder metallurgy, welding, galvanizing, oxidation and corrosion, to mention only a few, diffusion is all-important. Recent articles devoted to inter-diffusion of solid metals and to gas-metal diffusion are digested herewith.

Metal-Metal Diffusion

The influence of concentration on the rate of diffusion in solid metals was studied by W. SEITH & J. HERRMANN ("Zur Frage der Konzentrations abhängigkeit der Diffusion in festen Metallen," *Z. Elektrochem.*, Vol. 46, Mar. 1940, pp. 213-218). Specimens of lead and of various lead-magnesium alloys were welded together within iron tubing under dry hydrogen by means of spring pressure. The diffusion temperature and the welding temperature were identical. After the welding operation, the iron tubing was removed and the specimens heated in evacuated glass tubes. In order to cut the material for the chemical analyses, it had to be soldered into brass bushings.

The diffusion value for magnesium in lead is a function of the concentration. On the other hand, similar study of the diffusion of thallium in lead showed diffusion here to be independent of the concentration; the diffusion factor was distinctly higher than for self-diffusion in lead.

Magnetic property changes serve very well as indicators of diffusional modifications in metals, says P. CHEVENARD & X. WACHÉ ("Étude Thermomagnétique des Phénomenes de Diffusion dans les Métaux," *J. Physique & Radium*, Vol. 12, *Suppl. Bull. Soc. Francaise Physique*, No. 433, 1939, pp. 86-87), who made a thermomagnetic study of diffusion. A composite block of alternate carefully-annealed sheets of 2 nickel-iron alloys containing 33% and 73% Ni was hot-rolled in such a manner that practically no diffusion took place, while good cohesion was insured.

The equation $\log t = a + b/T$, where t = time for the diffusion process to be half completed and T = absolute temperature, was found to apply. At a constant temperature, t varies with the square of the thickness of the sheets. Plotting magnetization/temperature curves is considered to be a very sensitive method of keeping track of diffusion in metals and alloys.

The diffusion of various metals in aluminum was studied by A. BEERWALD ("Diffusion verschiedener Metalle in Aluminium," *Z. Elektrochem.*, Vol. 45, Nov. 1939, pp. 789-795). The strong tendency of aluminum to oxidize was a major difficulty in the determination of the diffusion factor. Permanent mechanical pressure had to be kept on the specimen, and this pressure was critical in obtaining good welds without stresses.

The diffusion of copper in aluminum between 457° C. and 505° C. ranged between $D = 7.31 \times 10^{-6}$ and $D = 1.10 \times 10^{-4}$ cm.²/day. For the diffusion of magnesium in aluminum between 395° C. and 577° C., D was found to range between 5.86×10^{-6} and 3.81×10^{-4} cm.²/day, respectively. Silver in aluminum showed at 465° C., $D = 1.68 \times 10^{-5}$, and at 573° C., $D = 3.04 \times 10^{-4}$ cm.²/day. Zinc in aluminum has at 415° C., $D = 2.09 \times 10^{-5}$, and at 555° C., $D = 4.35 \times 10^{-4}$ cm.²/day. Silicon showed at 465° C., $D = 2.95 \times 10^{-6}$, and at 600° C., $D = 8.00 \times 10^{-4}$ cm.²/day.

It was not possible to achieve good welding between aluminum and aluminum-manganese alloy; not even qualitative diffusion could be ascertained. Rules that usually apply to diffusion (concerning atom radius, valence electron number, saturation concentration) cannot be checked with the results on these metals.

Gas-Metal Diffusion

Gas diffusion in metals, and particularly hydrogen in steel, is a subject of considerable industrial importance. F. J. NORTON of General Electric Co. ("Diffusion of Hydrogen Through Steel," *J. Applied Physics*, Vol. 11, Apr. 1940, pp. 262-267) used the familiar steel-shelled radio vacuum tube as a micro-pressure gage to study the diffusion of hydrogen through its jacket after the protective paint had been removed by sandblasting. Hydrogen is produced on an iron surface in water, and the same reaction is known to occur also in high pressure steam boilers around 300° C. and is a possible factor in the embrittlement of boiler steel.

The steel shell of about 30 cm.² area in contact with water at 25° C. admits hydrogen at a rate of 0.13 microns/hr., but in contact only with water vapor no diffusion is observed. The addition of 0.1% sodium chromate to the water stopped diffusion. Zinc plating increased the rate of diffusion, but tin, cadmium, copper and nickel outer surfaces reduced it.

A vacuum tube constructed from stainless steel showed an initial rate half that of ordinary steel, which rate later fell off to practically zero. A coating of sodium silicate produced considerable diffusion of hydrogen even at 200° C. X (3)

Aircraft Engine Valves

"MODERN AIRCRAFT VALVES." A. T. COLWELL (Thompson Products, Inc.) *S.A.E. Journal*, Vol. 46, Apr. 1940, Trans. pp. 147-165. Descriptive review of design, materials, manufacture, inspection, operation and maintenance.

The major developments responsible for low valve temperatures and long service under high-output conditions are the sodium-cooled valve; forging technique, making possible one-piece, hollow-head valve; and cylinder-head design. The minor developments that have helped are the wide adoption of the austenitic steel containing 13-15% Cr, 13-15 Ni, 0.30-0.80 Si, 0.50 max. Mo, 1.75-3.00 W for exhaust valves; the use of Stellite or a similar hard-facing material puddled on the valve-seat; and the use of the aforementioned austenitic steel or one of the Silchrome type for seat inserts.

The seats of intake valves must be hardened to resist wear, and, when hardened, they must resist breakage. Bronze retainer locks give excellent service. The use of nitrided parts is increasing. Air-cooled cylinder barrels, formerly made of S.A.E. 4140 and oil-hardened, are now made of forged Nitralloy, and nitrided. When well-lubricated, the nitrided barrel gives considerably longer life. Many valve stems are also nitrided.

Sodium cooling keeps valve temperatures low enough to prevent intergranular corrosion of austenitic steels. The interior of sodium-cooled valves is carefully hand-polished to remove all scratches and tool marks, as these induce fatigue breakage. For small cavities, valves will operate satisfactorily with 35-80% of volume filled, with 60% optimum; larger cavities operate best with 40-50%. The heads are cleaned of deposit after service by making the valve the cathode in a molten mixture of 60% sodium hydroxide and 40% anhydrous sodium carbonate maintained at 800°-900° F.

The stamped letters formerly used in marking valves produced many fatigue failures. Now all marking is done with an electric pencil and with curved lines only. All Stellite seats are lapped before inspection to make defects easily discernible. In puddling, mixing the base steel with the Stellite causes porosity. Shrinks and cracks are caused by removing the flame too quickly from the molten Stellite. Super-finish is now being used for valve stems.

Valve breakage is the most serious type of field failure, and explains why so much care is given to design, steel inspection, finish, forging temperatures, and many other details. An unusual occurrence is the case-hardening of the inside of the valve by hydrocarbons in which the sodium is kept and absorbed by it. Another annoyance is a heavy deposit that builds up gradually,

A MESSAGE IN THE INTEREST OF NATIONAL DEFENSE

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finally unseating the valve, and eventually leads to burning. This condition is worst in warm weather, and with lean mixtures, high lead content, and oils that stew with a tarry, sticky residue. MS (3)

3a. Ferrous

Malleable Castings

"Malleable Cast Iron." H. G. Hall. *Foundry Trade J.*, Vol. 62, Mar. 21, 1940, pp. 223-228; Mar. 28, 1940, pp. 237-239. Up-to-date review.

According to the Malleable Committee of the British Cast Iron Research Assoc., "Malleable cast iron can be defined as any hard iron composition, cast into molds, free from graphite in the unannealed or hard state, and in which, after heat treatment, part or all of the carbide is transformed into temper carbon. If heat treatment takes place in an oxidizing atmosphere, the carbon is completely or partially removed by oxidation. The mechanical properties required of the finished product are governed by the method of heat treatment."

Fundamentally, however, although there are several types of malleable cast iron, softening of the brittle white cast iron is still controlled by (1) decarburization—the basis of the production of "whiteheart," or (2) graphitization—the basis of the production of "blackheart." Graphitization can be divided into two main stages: (1) Heating to and holding at a pre-determined maximum temperature until all the free cementite has been dissolved and the structure consists of saturated austenite and free graphite, and (2) cooling to just below the "critical" temperature (roughly 1325° F.) and holding there if necessary to ensure complete graphitization. The total malleablizing cycle ordinarily requires 200 or some hours.

"Short cycle" anneals have been developed that permit the reduction of total annealing time to a period of less than 24 hrs. The procedure consists essentially in (a) raising the temperature of the first stage of the cycle to give quicker attainment of equilibrium, (b) quenching from this temperature to the second-stage graphitization temperature rather than slowly cooling to this point, and (c) holding at this latter temperature just long enough to insure complete graphitization. Composition changes [higher silicon, lower carbon] are employed to hasten graphitization, and the time-wasting heating of excess container-weight is shortened by using light, small boxes and controlled atmospheres instead of inert packings.

Additional types of malleable have recently been developed, called "pearlitic malleable," "heat treated malleable" and malleable under various trade names, such as "Promal," "Z Metal," etc. Pearlitic malleable can be divided into two main groups, produced by (1) stopping the annealing process before graphitization is complete, or (2) reheating completely graphitized metal. Some combined carbon is always present—as pearlite, sorbite or even martensite. Almost any form of combined carbon can be produced, with tensile strengths ranging from 45,000-100,000 lbs./in.^{2} and elongations of 18% down to 1-2%.

The field of pearlitic malleable is extending in the same direction as that of various alloy steels. The advantages to be gained from a combination of very high silicon contents and the use of molybdenum are considerable. There is little danger of primary graphite being precipitated during casting even in very thick sections, and the high silicon will allow of a reduction in annealing time. Tensile strengths of 105,000 lbs./in.^{2} with 5% elongation, or 60,000 lbs./in.^{2} with 17% elongation can be obtained.

Pearlitic malleable irons are usually of higher strength and lower elongation than normal blackheart, the permeability is lower and the net shrinkage from pattern size is less than that of normal blackheart, probably due to incomplete graphitization. The machinability is obviously less.

The use of alloys to diminish the time of annealing rarely justifies the increased cost. Provided that the malleable produced conforms to a required specification, the engineer demands primarily maximum machining speed plus dimensional accuracy, plus reasonable finish, and it is doubtful if any alloyed malleable will give more satisfaction in these respects than correctly produced normal material.

British manufacturers have fought shy of the so-called short-cycle method. During the normal lengthy annealing cycle, inherent differences (due to different pig iron, melting practice, etc.) tend to be ironed out. The operation of the blast furnace and composition of the burden play an important part in the production of sound castings by the short-cycle anneal method. AIK (3a)

Stainless Steels

A Composite

The tremendous increase in production and consumption of wrought stainless steel in the last decade has come about not only through technical improvements in the properties and treatment of stainless but also through growing appreciation by metallurgical engineers (who have also been growing in number and importance) that stainless steel has important engineering as well as decorative utility. Early misapplications have dwindled remarkably and industrial acceptance of stainless increased since the day the engineer began to dominate the stainless steel picture.

An interesting survey of consumption and distribution factors in the stainless steel market is given by T. W. Lippert ("Stainless Steel—1939," *Iron Age*, Vol. 145, May 23, 1940, pp. 33-40), based on a questionnaire sent to about 3,000 stainless steel consumers. Collocation of the "finished steel" consumption figures thus obtained shows a total of over 100,000 tons of stainless to have been used in 1939, of which about 40,000 tons was strip; 25,000, bars and heavy rod; 21,500, sheet; 9,000, wire; 4,500, forgings; 2,500, tubular goods; and 2,000, plates and shapes. The 18-8 analysis accounted for almost 50% of the total consumption, with 16-18% Cr and 12-14% Cr next in order.

Industrial Distribution

Replies on distribution of outlet by consuming industries gave results in line with general expectations. The automobile industry is the largest single user of stainless steel, representing 38% of the total consumption; most of this is strip. Hundreds of tons of stainless go into body trim, steering wheel spokes, hub caps, gas tank caps, radiator grilles, miscellaneous hardware, etc. The lower price of chromium-plating still keeps many potential applications of stainless closed to it, however. There is now a growing tendency to use thin stainless facing shaped over heavy carbon steel backing to reduce costs.

The second major outlet for stainless is the food processing and handling field. Stainless is superior to glass in sanitation, is free of toxic elements and does not affect the taste, color, odor or composition of food or milk. Surface contaminations do form, however, on stainless steel food equipment — not through rusting, but through an accumulation of deposited material from the environment. Simple cleanliness plus sterilizing regulations demand frequent cleaning, methods for which are described by G. C. Kiefer of Allegheny Ludlum ("The Way to Clean Stainless Steel," *Food Inds.*, Vol. 12, June 1940, pp. 48-49).

Railroads and Aircraft

The third largest consumer of stainless as given by Lippert is the transportation industry (other than automobiles). The railroad industry uses much of it in its streamlined trains for trim or body structure or even complete construction, with weight reduction as great as 40% in some cases. Here, of course, the strength and corrosion-resistance of stainless are dominant factors in its choice.

The aviation industry also is a fast-growing user of stainless because of its high melting point and resistance to oxidation at high temperatures. [Its strength-weight ratio is highly attractive, too; cold-rolled 18-8 has the highest strength-weight ratio of any commonly used aircraft metal.] Recently, whole fleets of ships have been built with all movable tail surfaces and ailerons of stainless. Described in our May issue, pp. MA 282, 283, were Fleetwings's all-stainless-steel amphibian planes. Additional information on Fleetwings's design practice is given by C. de Ganahl ("Stainless Steel for Aircraft," *Steel*, Vol. 106, Apr. 29, 1940, pp. 46-48) and in another article E. J. W. Ragsdale of Budd ("Steel Aircraft," *Steel*, Vol. 106, May 6, 1940, pp. 70-71, 81) cites the advantages in aircraft of stainless steel's high fatigue strength and spot-weldability.

In a report on the marine-corrosion behavior of a number of metals and alloys used in aircraft, W. Mutchler & W. G. Galvin ("Tidewater and Weather-Exposure Tests on Metals Used in Aircraft," *Nat'l Advisory Comm. for Aeronautics*, Tech. Note No. 736, 1939) state that a molybdenum-bearing 18-8 exposed to the atmosphere rusted much less than other types of 18-8, and other stainless steels tested. Stainless steel panels exposed to the atmosphere corroded much less than those exposed directly to the salt water. All steels had been previously passivated, and samples of each had been shot-welded. In exposure to the atmosphere the shot-welds in several instances rusted faster than the remainder of the panel.

Process Industry Equipment

Lippert finds the chemical process equipment field to follow the transportation industry with respect to volume of consumption of stainless steel. Much stainless is used by the petroleum industry, and recently increasing interest has been shown in the application of *stainless-clad* steels for refinery service, where the corrosion-resistance of stainless sheet can be utilized at a fraction of its usual cost.

Several types of stainless-clad have recently been described—Babcock and Wilcox's stainless-clad chromium-molybdenum steel, in Metals and Alloys, Vol. 10, Sept. 1939, pp. 287-289; Kinkead's process in *Blast Furnace & Steel Plant*, Vol. 27, Dec. 1939, pp. 1245-1246; and Allegheny-Ludlum's Pluramelt in *Metal Progress*, Vol. 37, Feb. 1940, pp. 163-168. Methods of applying new stainless steel linings to old mild-steel refinery towers are described by C. Rogers ("Methods of Application of Chromium Steel Lining to Save Refinery Towers," *Ind. & Welding*, Vol. 13, May 1940, pp. 39-47), who says that even as costly as is the lining of a corroded vessel, the liner costs much less than would a replacement vessel.

Equipment for soap suds and sinews of war is poured from the same heat

CIRCLE L

***WORTHITE**

is a complex alloy. Developed by the metallurgists of the Worthington Pump and Machinery Corporation and the Lebanon Steel Foundry, it is produced in cast form exclusively at Lebanon.

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Worthite is only one of over two dozen alloys being produced regularly at Lebanon. Each of these alloys serves one or more specific purposes. Some of them have been developed for a special industry (Circle L 10, for example, was specifically developed for oil refinery service). Some of them, like Worthite, serve a variety of purposes and industries due to their successful resistance to corrosive action of many acids and alkalis.

Because of our wide experience over a long period of years you will find that our metallurgists can be most helpful in the selection of the right alloy steel for your purpose. It is on this basis that we like to sell our products and our services.

Lebanon STAINLESS AND SPECIAL ALLOY Steel Castings

Among the other process industries using large amounts of stainless, chiefly because of its corrosion resistance, are the pharmaceutical, glue, explosives, leather, lacquer, liquor, rubber goods, textiles, soap and pulp and paper. The applications of the various stainless steels in the pulp and paper industry are discussed by J. H. FAUNCE, JR. of Am. Rolling Mill Co. ("Stainless Steel in the Pulp and Paper Industry," *Paper Ind. & Paper World*, Vol. 22, May 1940, pp. 142-145), who gives a wealth of data on properties and treatment.

Additional large-volume stainless steel users cited by Lippert are the machinery, household equipment and building construction industries. The extremely broad industrial distribution of stainless applications is a reflection of the many-sided nature of such steels, which are not only attractive and corrosion-resistant, but strong and durable at low temperatures and resistant to oxidation and mechanical failure at high temperatures.

Some Properties

The heat-resistance of stainless steel is emphasized in some simple short-time high temperature tensile tests reported by H. V. THADEN ("Stainless Retains Strength at High Temperatures," *Machine Design*, Vol. 12, May 1940, p. 36). A piece of originally full-hard (185,000 lbs./in.^{2} tensile) 18-8 steel retained a strength of over 100,000 lbs./in.^{2} at 1,000° F., and even at 1300° F. the tensile strength was not under 50,000 lbs./in.^{2}

In spite of its high strength/weight ratio, cold-worked stainless steel with all its auxiliary advantages for aircraft and railroad service has been avoided by many designers because the "proportional limit" is very low. Also, the modulus of elasticity is somewhat lower in the cold-worked than in the annealed conditions, particularly in the direction of rolling.

According to R. FRANKS & O. BINDER of Union Carbide & Carbon Res. Labs. ("Effects of Low Temperature Heat Treatment on Elastic Properties of Cold-Rolled Austenitic Stainless Steels," *Tech. Pub. Am. Inst. Mining Met. Engrs.*, Feb. 1940), heating cold-rolled 18-8 steel at 400° F., followed by air-cooling, results in a much higher proportional limit, yield strength (0.2% set), and modulus of elasticity. This low-temperature heat treatment improves fatigue properties and toughness without adversely affecting corrosion resistance, and has no bad effect, either, on tensile strength or ductility. Treatment should be for at least 8 hrs. but less than 100 hrs. and the temperature range should be held to 400°-500° F.

The working properties of stainless steel sheet, strip and road are discussed by P. B. GREENAWALD of Carpenter Steel Co. ("Stainless Steel Rolled Products," *Trans. Electrochem. Soc.*, Vol. 77, 1940; Preprint No. 15, 8 pp.), and recent developments in stainless steel castings, including the introduction of silver-bearing stainless to resist salt water pitting corrosion, by G. F. LANDGRAF of Lebanon Steel Foundry ("Some New Developments in Corrosion-Resistant Steel," *Ibid.*, Vol. 77, 1940; Preprint No. 30, 4 pp.).

A review of 18-8 modifications suitable for fabrication by welding ("Advances in Stainless Steel—Its Fabricated Structure," *Can. Metals & Met. Inds.*, Vol. 3, Jan. 1940, p. 19) mentions, along with the need for columbium or titanium in the base metal and rod and maybe high silicon in the rod, the advisability of having higher-than-normal amounts of manganese in stainless steel parts that are to be dished or deep-drawn before welding.

German Nickel-free Steels

Germany's war effort has intensified her need to find substitutes for certain materials not of German origin, of which nickel is one. The Germans have developed and are evidently using a whole string of nickel-free stainless steels in which the nickel is replaced by suitable amounts of manganese, silicon or molybdenum ("Types of Stainless Steel Manufactured in Germany Pending Shortage of Nickel," *Wire & Wire Products*, Vol. 15, Feb. 1940, pp. 103-104).

Chromium-molybdenum steels contain 18% Cr and 1.2-1.8 Mo, and are applied to corrosion-resistant service; chromium-silicon steels contain 2.5-6.5% Cr and 2.5 Si and are employed for their scaling resistance; the chromium manganese steels contain either 16-18% Cr, 8 Mn and 1-2 Ni, or 10% Cr, 18 Mn and 1 Ni and are used for general corrosion resistance. A modification of the last, wherein the nickel is replaced by 4% Si is valuable for its scaling resistance. X (3a)

Cast Iron or Tool Steel Dies?

"DIES OF CAST IRON." RICHARD BREDENBECK (Advance Die & Tool Co.) *Iron Age*, Vol. 145, May 16, 1940, pp. 38-39. Practical.

Many dies formerly made from tool steel are now cast-to-form from high-strength cast iron. This is possible because of (1) the availability of high-strength iron with properties that provide design and manufacturing economies and good part-production life, and (2) the successful application of flame hardening to such iron.

Flame hardening of the irons in question (Meehanite) has lowered the cost of die construction, since in the original cases all the working edges had to be made from tool steel to avoid the warpage of the finished part that would accompany hardening. For instance, one grade of Meehanite has a minimum tensile strength of 50,000 lbs./in.^{2} and compression strength of 175,000 lbs./in.^{2} With heat treatment, the tensile strength becomes greater than 70,000 lbs./in.^{2} and compressive strength about 250,000 lbs./in.^{2}

The design of the part to be drawn or formed is important. High-strength iron, when properly hardened, ground and polished, practically eliminates "pick-up." A large punch or die with embossings and offsets can be cast-to-form in one piece and this permits considerable flexibility in design.

It is not advisable to use high-strength iron dies where there is a scraping effect on the blanked or sheared edges of a sheet during the operation of the die. VSP (3a)

3b. Non-Ferrous

Bearing Alloys—Tin-, Lead- and Aluminum-Base

A Composite

Ersatz and *Austausch* are words that suggest to most of us, among other things, an entire nation organized to overcome its raw-material deficiencies through the development of effective substitutes. Strangely enough, the Nazis may be breaking a few trails for American metallurgical engineers, for at least one of Germany's strategic materials, tin, is also an American deficiency. German efforts, therefore, to develop lead-base and aluminum-base substitutes for tin-base bearing alloys command our attention.

Attempts to develop lead-antimony bearing linings for railway use are reported by P. ZUNKER ("Versuche zur Entwicklung eines Lagermetalle auf Blei-Grundlage," *Metallwirtschaft*, Vol. 12, Mar. 22, 1940, pp. 223-230; Mar. 29, 1940, pp. 247-253). Tin-base babbitts, replaced many years ago in Germany by the alkali-hardened "Bahnmetall" (98.6% Pb, 0.7 Ca, 0.6 Na and 0.04 Li), had returned to favor for locomotive bearings, at least, as railway speeds increased. For car bearings, Bahnmetall has continued to be the German engineer's favorite.

Irish Stew Alloys

The difficulties of control of composition of Bahnmetall, of remelting scrap, the poor corrosion resistance, and softening in service if the bearing becomes overheated, all combine to make it highly desirable to replace Bahnmetall by some other alloy. Zunker took up this problem using lead-antimony as his base material. A total of 223 alloys were prepared as 7 oz. melts, and cast into hot molds (390° F.) as cylinders 0.9 in. in diameter, which were tested for compressive strength (to first crack), percentage of shortening in the compression test, and for Brinell hardness, all at room temperature.

After experimenting with many simpler alloys, Zunker favored those of about 70% Pb, 20% Sb and 10% "antimonide-forming metals," using small amounts of several of the latter. The idea seems to be to get a continual shower of different antimonides coming out as the alloy freezes and thus avoid large crystals. The alloys he considered most promising were: 72% Pb, 20 Sb, 1 Mn, 2 Cu, 1 Fe, 1 Cd, 1 Zn and 2 Sn; and 71% Pb, 18 Sb, 1 Mn, 3 Cu, 1 Fe, 1 Cd, 1 Zn, 3 Sn and 1 As, with perhaps 0.7 Te.

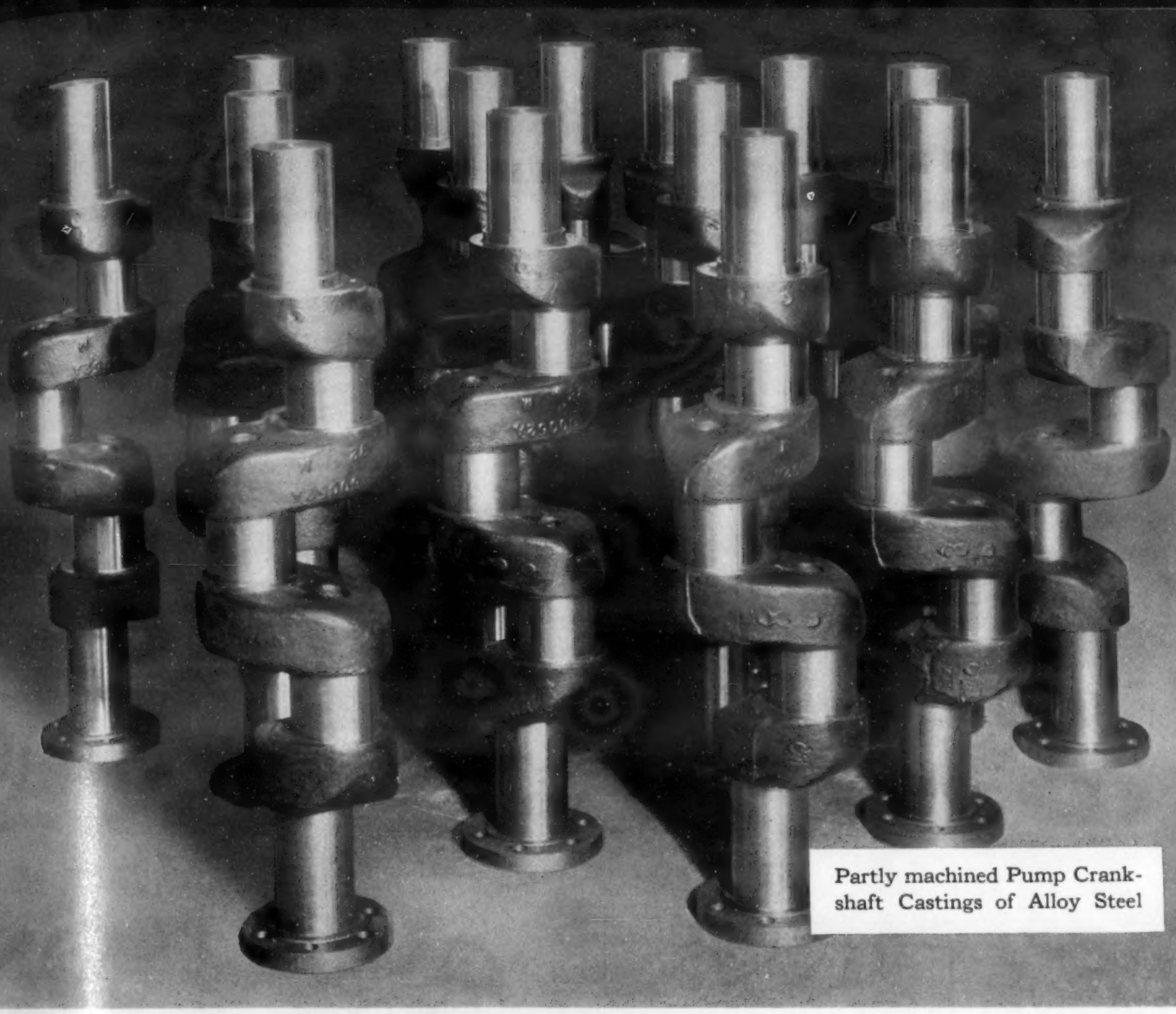
However, the properties of these "Irish stew" alloys were not materially different from those of Einheitsmetall (80% Pb, 14 Sb, 5 Sn, 1 Cu) which the German railways used during the World War and then abandoned as soon as they could again get tin. Zunker realized that behavior as actual bearings cannot be appraised from the room-temperature tests he made, but he was called off the work before operating-temperature tests could be made, because since he started the work, the German raw material situation had changed so that the use of a lead-base bearing metal was just as bad from the German strategic metals point of view as the use of tin-base.

The experimental work reported didn't get anywhere, but the side lights are definitely interesting as showing that, for severe duty, the German railways prefer tin-base babbitt, and that Bahnmetall is not really as satisfactory as many earlier German publications led one to believe.

Other Lead-Base Alloys

Zunker's conclusion that the best hope for a tinless, lead-base babbitt lies in a lead/antimony ratio of 70/20 plus up to 10% of a multiplicity of other elements, is not shared by M. F. VON SCHWARZ ("Neue Blei- und Aluminium Lagermetalle," *Giesserei*, Vol. 27, Apr. 19, 1940, pp. 137-144), who describes a series of lead-antimony-arsenic alloys ("Palid"). Their compositions range from No. 5 with 5% Sb, 5% As, with or without up to 2% Cu, Ni or Cd, or smaller amounts of copper plus nickel, through No. 6 with 8% Sb and 6% As, to No. 7, with 11% Sb and 7% As—all with lead as the remainder.

Chief attention is centered on No. 6, which is aimed to duplicate the performance of WM 80 (80% Sn, 12% Sb, 6% Cu and 2% Pb), the German standard high grade babbitt. The composition is aimed toward producing the ternary eutectic. The structure is shown to be fine. The freezing interval (520°-560° F.) and the casting



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temperature (650°-700° F.) are around those for the tin-base babbitt; the Brinell hardnesses are:

	70° F.	220° F.	212° F.	265° F.	300° F.
Tin-base (WM 80)	28	20	11	8	7
Lead-base (Palid No. 6)	23	21.5	13	8	6.5

Tests were run by the government testing laboratory at Berlin-Dahlem on a bearing-testing machine using an actual sleeve bearing and shaft, the bearing being 20 mm. long by 60 mm. inside diameter, clearances generally 2% of the diameter, and the lining thickness of the Palid specimens 0.8 to 1 mm.; the back material and the shaft hardness and surface finish are not stated.

Coefficient of friction and the temperature rise tests showed no appreciable differences in performance of the tin-base and Palid No. 6 bearings save that at low speed, 1 m./sec., the friction for Palid No. 6 was 3 times that for the tin-base bearing. The clearance of the lead-base bearing used on this test was 1.33%, that for the comparative test on tin-base, 1.5%. In tests with increased pressure and decreased oil supply to produce failure, the lead-base bearing stood higher load than the tin-base, with the surface still smooth after the bearing had started to squash out.

The government laboratory report pointed out that no tests were made and no conclusions can be drawn as to behavior under shock loading. No account is given of any actual service tests, nor are any laboratory wear data included.

Von Schwarz alleges that not only is the lead-base alloy a complete substitute for the tin-base alloy, but that it is definitely superior. No evidence is given as to its ability to bond to a bearing back. The statement is made that, in practice, a lining thickness of 0.25-0.30 mm. would be used, which would reduce any tendency to fatigue under shock loading, and that a three-layer bearing is being developed, with a steel shell carrying a welded-on layer of copper upon which a layer of Palid is cast.

Effect of Arsenic

The alloy seems similar to the ordinary high-lead babbitt (about 75% Pb) with around 15% Sb, 5-10% Sn and 2% Cu, but with the antimony held a bit lower and arsenic substituted for tin and copper. Another modification is the so-called Thermit babbitt, similar to the ordinary lead-base babbitt plus around 1% each of nickel, cadmium and arsenic. The effect of arsenic in improving high temperature strength is well known, but most previous investigators steered away from over 2% As on account of brittleness, and in general, some tin has been retained in an arsenic-containing babbitt to develop a couteracting toughness.

Wegener (METALS AND ALLOYS, Vol. 3, May 1932, pp. 116-119) commented on the improvement in freedom from segregation conferred by arsenic, but warned against the use of too much on the score that a very fine structure (such as von Schwarz shows for Palid No. 6) is poorly wear-resistant. The discussion of a paper by Roast and Pascoe (*Trans. Am. Inst. Mining & Met. Engrs.*, Vol. 68, 1923, p. 735) brought out much comment as to the brittleness and lack of adhesion to the backing of lead babbitts containing appreciable arsenic. In this connection there should be noted the guarded comment of the German government testing laboratory that the Palid babbitt had not been tested under shock loading.

Not content with finding an alleged complete substitute for tin-base babbitt, von Schwarz also claims the development of an aluminum alloy as a substitute for *bearing bronze*, but description of this is postponed for a subsequent issue of *Giesserei*. The bronze-substitution angle is interesting, since much of the effort put on aluminum-base bearing metals has been from the babbitt point of view, even though (as was noted on p. MA 280 of the May issue of METALS AND ALLOYS) the requirement of hard shafts tends to throw them into the category of copper-lead, copper-tin-lead, or regular bronzes.

Aluminum Alloys

Shaft-scoring with aluminum-base bearings occurs because in the alloys heretofore available the intermetallic compounds present are more brittle than those in white-metal bearings, and the matrix also is harder. Von Schwarz evidently accepts this as inevitable and is working toward replacement of bronze by aluminum. But M. ARMBRUSTER ("Uebersicht über die bisherigen praktischen Erfahrungen mit Leichtmetallagern," *Metallwirtschaft*, Vol. 19, Feb. 16, 1940, pp. 127-133), still looking for a substitute for babbitt, attempts to overcome this shaft-scoring disadvantage by developing aluminum-base alloys with a different type of microstructure—one in which *soft* secondary constituents are imbedded in a relatively soft aluminum matrix.

The alloy addition chosen should harden the aluminum matrix as little as possible. Analyses are not given, but brief reference is made to the fact that additions of tin and lead are employed in the successful aluminum-base bearings. Two such German bearing alloys are designated as "Almadur M23" and "Almadur MP6". Data are given on the hardness of the aluminum bearings (40-50 Brinell at room tem-

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perature) and babbitt bearings (20-30 Brinell at room temperature) over a range of temperatures. Compression properties indicate that the plasticity of the aluminum bearings approaches that of the white metal bearings.

The impact fatigue limit of MP6 is 2.5 times that for white-metal bearings containing 86% Sn. With good lubrication, aluminum-base bearings exhibit good frictional properties at heavy loads — higher than can be carried by white-metal bearings. Because of the high thermal expansion of the aluminum bearings, adequate clearance must be insured. Forced lubrication is of value in that the lubricant removes a large amount of the heat developed at the friction surfaces. HWG + GA (3b)

Aircraft Fuel Tanks of Aluminum Alloy

"Aluminum Aircraft Fuel Tanks." E. H. Dix, Jr. & R. B. Mears (Aluminum Co. of America) *S.A.E. Journal*, Vol. 46, May 1940, Trans. pp. 215-220. Descriptive.

Aluminum alloy fuel tanks have been used for nearly 20 yrs. because of their light weight, ease of fabrication, and high resistance to corrosion. The alloys used include the non-heat-treatable 2 S, 3 S, 4 S and 52 S alloys principally for removable tanks of welded construction; the heat-treatable alloys 17 S and 24 S principally for integral tanks of riveted construction; and Alclad 3 S, 17 S and 24 S sheet. The corrosion resistance of the non-heat-treatable alloys is relatively high and is superior to that of the heat-treatable alloys. The corrosion resistance of Alclad sheet is exceptionally high.

Dry gasoline does not corrode aluminum, and, in general, results obtained in service have been entirely satisfactory. In isolated cases, pitting by corrosion has occurred, but in such cases corrosion was invariably caused by water, contaminated with chlorides, bromides or heavy metal compounds, lying in the bottoms of the tanks for extended periods. Corrosion has occurred in some cases in aluminum alloy tanks in which copper or brass parts had been used or where there was contact between two aluminum alloys having different solution potentials.

Corrosion can be prevented by designing tanks to permit free drainage of water to the sump; selecting metals throughout the tank to avoid electrolytic action; handling fuel so that it will not pick up water, iron rust or other heavy metal corrosion products prior to the time it is introduced into the fuel tank; applying to the tank interior suitable coatings, such as those produced by the Alrok and anodizing processes, and paints made with phenolic-resin vehicle and zinc chromate pigment; the use of Alclad sheet, as the surface layer in this case protects the core mechanically and electrochemically; the use of a corrosion inhibitor, such as sodium chromate; periodic cleaning of tank interiors or flushing them with inhibited solutions; and dehydration of the gasoline used. MS (3b)

Corrosion of Insulated Fine Copper Wires

"Causes of Corrosion of Fine Copper Wires Carrying a Potential." H. N. Stephens & G. B. Gehrenbeck. *Elec. Engineering*, Vol. 59, June 1940, pp. 357-360. Investigation.

Copper corrosion is a serious problem in electrical equipment such as coils containing fine wires used in radio and ignition systems. In the past, causes of failure have been assigned to free acids in the insulating material and to moisture absorption, since conditions of high humidity tend to increase the failure of the coated wire.

An accelerated corrosion test was devised with two parallel bare copper wires at a potential difference of 90 (later increased to 250) v. d. c. held under tension against the surface to be tested, under conditions of 90% relative humidity and 120° F. The specimen was placed on the bowed surface of a molded block with two binding posts at each end and was held in position by two parallel bare copper wires, spaced 3/16 in. apart and each held under slight tension by a pair of binding posts. Originally, No. 40 wire was used but later No. 32 wire was substituted and the amount of corrosion estimated microscopically. At 90 v., the test lasted 4 days.

Electrical tape adhesives of the rubber-resin type offered the best corrosion protection. All types of glue including the dialyzed variety were found in this test to be highly corrosive. Furthermore cellulose in the presence of water caused corrosion of the copper wire. The following table giving the insulation resistance at 120° F. and 90% humidity of several fibers shows the superiority of cellulose acetate over the ordinary commercial fibers even after purification by extraction:

Tape Material	Megohms	
	Unextracted	Extracted
Rayon (Viscose)	3	112
Linen	4	
Silk	20	4000
Wool	1700	1400
Cellulose Acetate	5000	10000

The authors conclude that the most satisfactory and practical construction for a corrosion-free electrical tape for copper wire is cellulose acetate coated with a good quality rubber-resin adhesive. FHC (3b)

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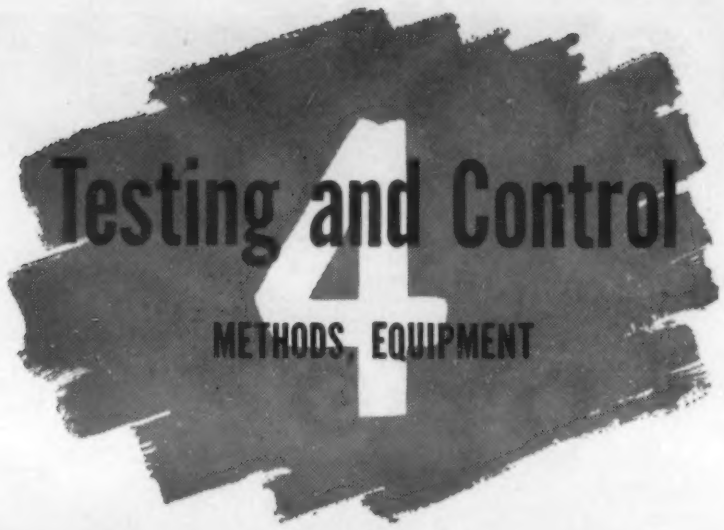

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Photoelasticity and Design

A Composite

"Photoelasticity provides a photographic method of showing the distribution and magnitude of stresses produced in structural and machine parts under load." This functional definition is offered by O. J. HARGER & T. V. BUCKWALTER of Timken Roller Bearing Co. ("Photoelasticity as Applied to Design Problems," *Iron Age,* Vol. 145, May 23, 1940, pp. 42-50) in an excellent review of photoelastic analysis.

If a machine member must have one groove, it may be stronger if several grooves are used; an annular groove near a press fit increases fatigue strength; bolts are made stronger by removing metal. Many such design changes that give improved stress distributions are indicated by photoelastic analysis. Failure of a part usually occurs in a region of localized stresses, or stress concentration. Photoelastic analysis enables the designer to locate these regions and to alter the design rather than employ the generally undesirable practice of making the part larger.

A model of the design part to be studied is machined from a flat piece of some isotropic transparent material (usually a "plastic") such as Bakelite, Marblette, etc. The model is loaded in a manner that simulates service conditions. Polarized light from a mercury vapor lamp is passed through the stressed model; each element acts as a double refracting crystal giving an interference effect—a series of bands or fringes spaced one wave-length of light apart, which indicate the magnitude and distribution of shearing stress in the model.

The magnitude of the stress is proportional to the order number of the interference bands, and each fringe passes through points in the model that have the same value of shearing stress. Such results on *plastic* models can be applied to actual *metal* members because they are independent of the elastic constants of the materials so long as the stresses are below the elastic limit.

Optical equipment used and some simple applications to practical engineering design are described. Photoelastic tests are often used to correlate and supplement other tests, such as fatigue, abrasion, etc., on actual design parts. In some cases photoelasticity is unable to provide satisfactory numerical values of stress concentration.

A comprehensive and detailed review of the fundamentals of photoelastic analysis as well as its applications to his own stress-distribution problems is given by R. E. ORTON of Acme Steel Co. ("Photoelastic Analysis in Commercial Practice," *Machine*

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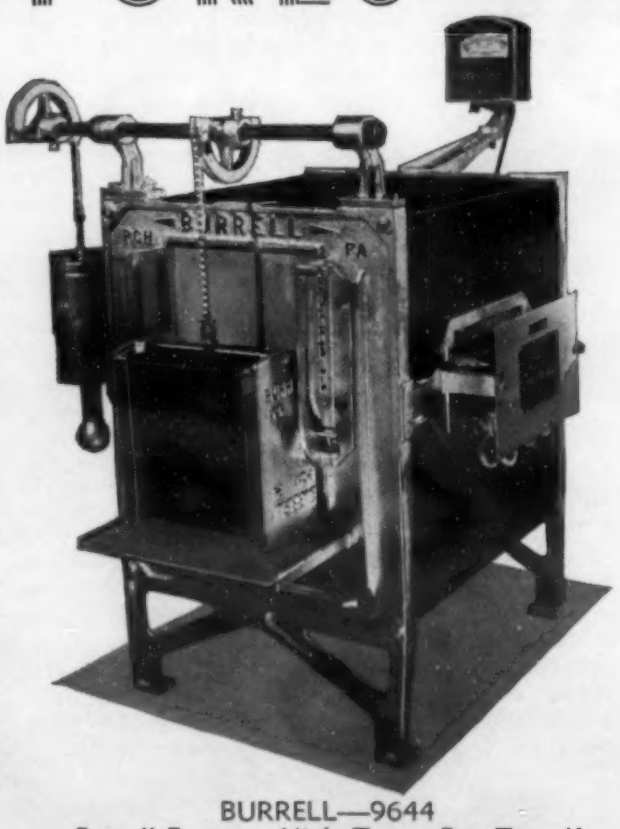

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Design, Vol. 12, Mar. 1940, pp. 31-35, 84, 86; Apr. 1940, pp. 39-41, 74, 78; May 1940, pp. 50-53, 102, 104, 106; June 1940, pp. 55-58, 72, 73; concluded in July. X (4)

Electrolytic Etching of Brass

"The Electrolytic Etching of Brass." G. C. Williams (Univ. Louisville) & G. Rieger (Univ. Minnesota) *Trans. Electrochem. Soc.*, Vol. 77, 1940; Preprint No. 20; 4 pp. Original research.

Very satisfactory etching of brass has been obtained with the following solution in which the specimen is made anodic at 2 amps./in.^{2} (31 amps./dm.^{2}): 10 ml. 0.10 M. ammonium acetate, 30 ml. 14 M. ammonium hydroxide, 30 ml. 0.50 M. sodium thiosulfate, and 30 ml. distilled water.

The time required for etching varies with the composition and previous treatment of the specimen, but results may be readily duplicated. In general a shorter etching time is required for samples high in copper, and hard-worked specimens require longer than annealed samples. This electrolytic method is especially useful for hard worked specimens, as they are not always satisfactorily etched by chemical etchants. AB (4)

Steel Inclusion Classification

"Classification of Inclusions in Steel." *S.A.E. Journal*, Vol. 46, June 1940, pp. 17-19. Proposed S.A.E. recommended practice for rating steel for cleanliness.

This classification is intended to cover alloy and carbon steel bars, billets, and slabs up to 10 in. wide by 5 in. thick, also special sections, except sulphur-bearing and all other free-machining steels.

Where possible, the surface to be examined is ½ in. x 1 in. When the cross-section is large enough, the micro specimen is cut so that the face to be polished is in the center plane of the sample and is divided into two equal parts by a midway plane. The ½-in. direction must be parallel to the direction of rolling. If the sample is not large enough, the specimen is cut so that again the ½-in. dimension is in the direction of rolling and the 1-in. dimension is the radius of cross-section of the bar.

Polishing may be facilitated by quenching from above the Ac_3 range. Polishing may be done by any desired technique. In fine polishing, direction of the polish should be at right angles to the direction of rolling. The polished specimen is placed on the microscope stage and each individual field of entire polished area is projected successively on a ground glass screen at 100 diameters. The ground glass is ruled with a series of parallel lines ½ in. apart.

From observation on the ground glass, 3 classifications are made in sequence. The length of the longest inclusion present is represented by a number which corresponds to the number of units (one unit-distance between ruled lines) that the inclusion covers on the screen. Only the nearest whole unit is recorded. Suffixes are used to designate certain characteristics. These are *T* for thin (1 mm. or less in width); *H* for heavy (3 mm. or over in width); *d* for disconnected; *vd* for very disconnected; and *g* for group. A discontinuity of not less than 1 unit along the length of inclusion being rated arbitrarily divides the inclusion into two inclusions.

The average length of all inclusions other than the longest and over 1 unit in length is designated by a number equivalent to the number of units covered by the average length inclusion, with a suffix indicating the number of inclusions rated in arriving at this average. Background rating is designated by a letter (A, B, C, D) and includes all inclusions less than 1 unit in length. For rating background quality, accompanying standard pictures are provided. A contains the smallest amount of inclusions and D the greatest.

As an example, the general form of rating will be 7-2^3-B. This means that the largest inclusion in the specimen is 7 units long, all other inclusions are 3 in number with an average length of 2 units, and the background may be represented by "photograph B." MS (4)

Measuring Conductivity

A Rapid Method for the Determination of the Electrical Conductivity and Its Temperature Coefficient ("Ein Schnellverfahren zur Bestimmung der elektrischen Leitfähigkeit und ihres Temperaturkoeffizienten") Albrecht Kaufman & Ludwig Mollwo. *Z. Metallkunde*, Vol. 31, Nov. 1939, pp. 344-347. Descriptive.

Resistance measurements on small samples are usually performed by the null method using d.c. Owing to thermoelectric effects, adjustments are constantly necessary and 2 measurements have to be made, reversing the current in the second determination. It is, therefore, "extremely difficult, if not impossible" to record temperature-resistance curves or to register rapid changes in resistance.

These difficulties can be eliminated for non-magnetic materials by using a.c. for determining the resistance and by employing apparatus incorporating modern amplifier and rectifier advances. A diagram for the resistance testing equipment operating at 50 Hz and for a recording instrument are shown. Resistance as low as 10^{-4} ohm can be measured quickly, and with an accuracy of better than 0.5%.

The application of the new testing equipment is demonstrated by three examples: (a) The allotropic transformation at 435° F. and the hysteresis in the temperature-resistance curve of 99.4% pure thallium: (b) the rapid decomposition of the β-phase in aluminum-zinc alloys; and (c) the detection of minute changes of resistance, specifically in a 30% copper-nickel alloy in the temperature range of 850°-1200° F. EF (4)

Microscopic Hardness Testing

A Micro Hardness Tester ("Ein Mikrohärteprüfer") Heinrich Hanemann & E. O. Bernhardt. *Z. Metallkunde*, Vol. 32, Feb. 1940, pp. 35-38. Descriptive.

Brinell, Rockwell and Vickers hardness measurements are a macroscopic determination of the amenability to plastic deformation of aggregates of crystals. Their distribution and size in the case of two or more constituents of different hardness influence the testing result. There is a demand for a method for the highly-localized determination of hardness.

The Zeiss-Jena Co., in collaboration with the Technische Hochschule, Berlin, has developed an ingenious microscopic hardness tester. The indenting body, a quartz or diamond pyramid, is directly mounted on a lens, through which the indentation is measured microscopically. For softer materials, a quartz lens and indenter are used in conjunction with glycerine as the immersion liquid and monochromatic light of 5.461 A.U. wave length. For harder materials, a diamond pyramid of 0.8 mm. width mounted on a front lens of 2.3 mm. diameter is employed. The construction of the new instrument and the rather ingenious application of the load are given in detail.

The identification of various phases of heterogeneous materials is considered as an important and novel field of application. This is demonstrated by some micros of aluminum alloys, with their notoriously great number of crystals. The different hardnesses between segregated crystals and their surrounding matrix, and the hardness variations inside of a solid solution not in equilibrium with a second segregating phase are shown. The testing of carburized or nitrided layers, electrolytic platings, of electrolytically oxidized aluminum alloys, of intermediate layers after soldering and brazing, of hard crystals in bearings and high speed steel, and of hard carbides offer a wide field of application.

One surprising observation was that many crystals heretofore considered as "glass-hard and brittle" could be tested due to the minuteness of the indentation. Even minerals of such high hardness and simultaneous brittleness as spinel and corundum displayed in microhardness testing a "plastic behavior resembling that of metals." Blast furnace slags, enamels, glasses, porcelain, cement and grinding wheels were as successfully tested for hardness as were bones, teeth and surfaces strain-hardened by polishing. EF (4)

Steel Spectrography

"Spectrographic Analysis of Steel." J. L. Gregg & P. R. Irish (Bethlehem Steel Co.) *Iron Age*, Vol. 145, May 5, 1940, pp. 33-37. Practical description.

A spectrographic procedure for steel analysis developed by Bethlehem Steel Co. determines rapidly and economically all elements commonly found in steel, with the exception of carbon, sulphur and possibly phosphorus. The accuracy is said to be excellent, provided elements are not present in amounts exceeding 3-5%. Even in higher concentrations, the elements may be determined accurately enough for routine control. The most desirable specimen is a rod of 7/32 in. diameter. Except for a few elements present in very small quantities, a high-voltage discharge is used in practically all determinations. All elements determined may be obtained on the 10-in. plate used in the Littrow spectrograph.

Analyses with arc discharge are made for copper below 0.02%, tin below 0.10%, chromium below 0.02%, aluminum below 0.10%, vanadium below 0.02% and molybdenum below 0.10%. The spectrograph used is a Littrow instrument, which for practically all work is set for the range 2,650-4,000 A.U. The usual scale printer has been replaced by a bar covering one-half the area of plate exposed and operated so that two different kinds of exposure are obtained with a single sparking. As many as 18 exposures are made on a single plate. The plates are developed for 1 min. in D-8 developer and left in hypo until cleared (30 sec. for Eastman and 1½ min. for Cramer plates). They are then washed for ½ min. and dried in a heater at high temperature.

The density of the selected lines on a plate is determined with a microphotometer. For each plate certain iron lines are microphotometered and from these readings a gamma curve is drawn. The densities of the desired lines of the elements to be determined and certain iron lines are read with the microphotometer. From the readings the amount of each element is obtained by operation of a transposing board. Spectrographic results are based on calibration curves determined from samples of known composition. VSP (4)

books

Elements of Metallurgy

METALLURGY FOR ENGINEERS. *By E. C. Rollason. Published by Edward Arnold & Co., London; Longmans Green & Co., New York, 1939. Cloth, 5¾x8¾ in., 272 pages. Price $3.00.*

This is an introductory text book in physical metallurgy, which, the preface states, is intended to carry the student on to the point where he can read specialized publications with profit. It is expected to be used "in conjunction with a teacher." Save that the preface says it is a text book for a course required for engineering students, the contents do not bear out the expectation which the title might arouse, that the point of view differs from that of the usual introductory text book. The author is concerned with what metals and alloys are good for, but so is the author of any respectable text book on metallurgy. He refrains from being very high brow, but that is essential in any elementary treatise.

With the object of giving a smattering of the physical metallurgy of both ferrous and non-ferrous alloys, a wide variety of topics is touched upon. Within the limits set by the small size of the book, the job is rather well done. We would rank it in the upper third in the dozen or so books of its type.—H. W. GILLETT.

Metallography

PRACTICAL MICROSCOPICAL METALLOGRAPHY. THIRD EDITION. *By Richard H. Greaves & Harold Wrighton. Published by D. Van Nostrand Co., Inc., New York, 1940. Cloth, 6¼x9½ in., 272 pages. Price $6.50.*

This edition follows the pattern of the previous ones, with some revision and enlargement. The purpose is to describe the methods of microscopical metallography and to instruct in the interpretation of structure, especially by showing typical micrographs. This is reasonably well accomplished for a large majority of the cases that arise in general practice.

One would have liked micrographs to show the utility of the microtome for soft metals, and of electropolishing—matters that are mentioned but not illustrated. Something might have been said about taper grinding in the study of metallic coatings. Grain size determination is mentioned, but only the McQuaid-Ehn method for steels is cited. The structures produced by austempering are not discussed.

The meaning, in terms of mechanical properties, of the changes in structure brought about by various treatments, is discussed very briefly, but sufficiently to bring out the fact that micrographs are not just pretty pictures to adorn a report but that they have an engineering meaning. The metallurgy thus brought in is sound but sketchy, and references to sources of information are few. Even in the exact field of the book there are almost no references at all. Authors whose avowed purpose it is "to show typical micrographs" would have been expected to let the reader know of the existence of the "Atlas Metallographicus." And in discussion of objectives and technique, a reference to Vilella's "Metallographic Technique for Steel" (published by Amer. Soc. Metals, Cleveland) would have been in order, since his demonstrations of what not to do are even clearer than the discussion given by Greaves and Wrighton.

The older editions of this book were good, this one is better. Metallographers will be glad to have it on their shelves.—H. W. GILLETT.

Metal Specifications

A.S.T.M. STANDARDS—1939. PART 1—METALS. *Published by Am. Soc. Testing Materials, Philadelphia, 1940. Cloth, 5¾x9 in., 1308 pages. Price to non-members $8.00.*

Every three years a complete set of A.S.T.M. specifications is printed. New specifications and revisions of old ones adopted in the interim are given in yearly supplements. The 1939 set thus collects all those in effect at the moment. The volume dealing with metals includes some 225 standard and tentative specifications for ferrous metals, 120 non-ferrous and 20 on testing methods applicable to both.

Many of these have been accepted by the American Standards Assoc., the A.S.M.E. Boiler Code, the Assoc. of American Railroads, or the Society of Automotive Engineers, or are endorsed by the American Foundrymen's Assoc. In such cases suitable notation is made.

Since the specifications are agreed upon by representatives of producers and consumers, and pass through years of discussion and formulation, then through more years of use as "tentative," before they grow up into "Standard," they represent considered opinion and experience. Nor are they entirely sacred after adoption as standard for they are subjected to constant scrutiny and to revision as accumulated knowledge requires. A large and important part of the A.S.T.M. activities resides in the committee work that applies new information (and often gets new information by research planned directly for the purpose) to the improvement of specifications and methods.

So much useful metallurgical information is collected by the A.S.T.M. that every metallurgical engineer should keep in touch with its activities, and, of course, have this volume of standards on his shelves.—H. W. GILLETT.

Alloy Dictionary

A DICTIONARY OF METALS AND THEIR ALLOYS. *Edited by F. J. Camm. Published by Chemical Publishing Co., New York, 1940. Cloth, 5¾x8¾ in., 245 pages. Price $3.00.*

Worth thirty cents, on the off chance that it may contain the trade name of some obsolete alloy one might wish to look up. The book bears the statement "first published 1940," but in general reads as if "edited" from publications of about 1890. Electrolytic copper is said to contain about 99.86 per cent Cu. Chromium plating "should be done out of doors," Keep's drill test is "one of the four chief systems of testing the hardness of metals."

The author is "editor" of other books, such as "Practical Motorist," "Practical Wireless," "The Cyclist," etc. While the book bears an American imprint on the title page, it appears to have been printed in England; page 19 says "aluminum—the American rendering of our word aluminium." We cannot imagine an English metallurgical engineer so devoid of a technical library that this book would be of any use to him. It seems to be written in the hope of selling it to mechanics who want to know something about metals, but it would be a shame to take their money.

Some of the British journals remark on the necessity of conserving paper in war time. The Minister in Charge of Paper Conservation might well have started with this, for in the words of eminent British authors, "it never would be missed."—H. W. GILLETT.

Other New Books

WITH HAMMER AND TORCH (MED HAMMARE OCH FACKLA) VOLUME 10. *Published by Sancte Örjens Gille, Stockholm, 1939. Paper, 6¾ x 9¾ in., 178 pages.* Another volume in this history of metal working in Sweden.

METALLURGICAL ENGINEERING

shop notes

Removing "Flash" from Die Castings

by C. R. Maxon
New Jersey Zinc Co.

All die castings have a fin or flash at die partings which must be removed by the die caster or by the die casting user. The following method of doing this may be helpful, particularly if the parts in question are to be plated:

The flash usually comes at the widest section of the casting and is removed by forcing the part through a shaving die made to conform to its contour. When kept sharp, such dies do an entirely satisfactory job, but they sometimes leave small particles of flash to be removed in a subsequent polishing or buffing operation. If the part is irregular in shape and is to be plated, it may require an unnecessary amount of time and care in getting the polishing or buffing wheel to remove all traces of the flash.

To avoid this, and still produce parts meeting exacting requirements, a burnishing operation may be performed at the same time that the flash is removed, at little, if any, additional cost. This is accomplished by making the shaving die slightly smaller than the casting at the section where the flash appears, by an amount approximating 0.0015 to 0.002 in. on a side. Also, instead of leaving the edges of the die sharp and substantially square, as is common practice with ordinary dies, these edges can be "broken" or slightly rounded with fine emery cloth.

When a casting is forced through a shaving die made in this way, the flash is not only sheared off, but the casting is burnished where the flash appeared and at each side of the plane of the flash, leaving a surface which is remarkably smooth and which can be buffed in less time than would ordinarily be required.

Burnishing by this means requires extra pressure in forcing the casting through the die. Zinc alloy die castings are particularly well suited for this operation as they are ductile and can withstand the extra pressure required. The work is readily done in a punch press and, presumably, in other types of presses. This practice is not intended to take the place of trimming in the usual way, but, under certain conditions as mentioned above, it has resulted in real economies.

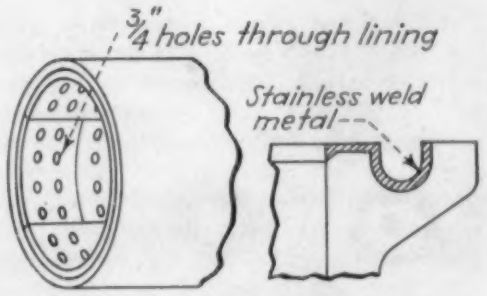
Hard-facing a stamping and forming die for oil-can ends with Stellite permitted the substitution of mild steel for more expensive tool steel. Because the life between grinds was increased about 9 times, the hard-faced dies eliminated nearly 90% of the shutdowns for regrinding. Under normal conditions each of the dies makes approximately 20,000 cuts per day. —*Oxy-Acetylene Tips,* Linde Air Products Co.

Lining Refinery Vessels

by Ronald Lett

In the large oil refinery with which the writer is connected, intelligent application of stainless steel welding rod has been profitable from more than one standpoint.

For many years the reaction chamber and certain sections of the towers of the various stills that come into contact with acids and chemicals were metal-sprayed with



aluminum (and in certain cases with lead) several times a year. In order to do this, the chambers had to be grit-blasted, a practice that entailed much labor and cost.

This metal-spray design has been replaced with a stainless steel lining, which is rolled to the contour of the chamber and plug-welded with a suitable stainless steel electrode (Lincoln Stainweld, for example) on 4-in. centers through ¾-in. holes in the sheeting. The system is then tested by compressed air and soapsuds for leaks. This installation permanently resists all chemical action.

The ring-type flange leaks when the least corrosion sets in at the groove, so much so that this type of flange, which carried certain acid-bearing oils in its lines, had to be changed constantly.

These flanges are now machined, at the groove, larger than the eye of the ring, filled-in with stainless weld metal and then machined to size. This is a ticklish job because if there is the least bit of slag inclusion or porosity, the flange has to be remachined and filled in again. The stainless weld metal surface makes the groove absolutely corrosion-resistant and thus far more serviceable.—*The Welder's Stabilizer,* Lincoln Electric Co.

Repair Defective Castings?

by Herbert R. Isenburger
St. John X-Ray Service, Inc.

The problem of whether to repair a defective casting by welding or to place it in service if the defect is really harmless—or perhaps, to replace it altogether—is one that many foundrymen and engineers must often meet. The following practical case with which the writer had direct contact, through X-ray inspection, may serve to guide others.

A certain 12-in. steel angle valve body casting not intended for high-pressure steam service, yet required to be as nearly perfect as possible (for reasons of inaccessibility after installation) was X-ray inspected. Only one defect, a pipe shrinkage condition shown by "double exposure" technique to be in the center of the wall, was revealed.

Considering the service requirements, it was suggested that the casting be used "as is" because a sufficient thickness of sound metal remained between the inner surface and the defect. But the customer insisted that the casting be repaired, so a reliable foundry was assigned to repair it. Under our personal supervision the bad metal was chipped out, and after the area was completely cleaned up about ½-in. of sound metal remained toward the inner surface of the casting. The cavity was then welded up, in our absence.

Surprisingly enough, visual inspection the next morning showed the casting to have been welded not only from the outside, but also from the inside. It seemed that the beginning of welding had cracked the casting through the wall in one spot, leaving a ⅜-in. hole that had to be welded from the inside, too. On the surface the job looked perfect.

But the exograph revealed a very porous weld, a weak region that would probably cause trouble sooner than could the original unrepaired shrinkage. This case and many similar lead us to contend that it is better to use a defective steel casting, if the defects are located where they are not harmful, rather than attempt to repair such conditions. If a casting is so defective that it needs repairs, it is often better to replace it altogether.

Users of industrial ovens should find the following application of hard-facing of real value. Quite often an entire oven-door mechanism must be replaced or dismantled because the latches become very badly worn away. A thin layer of hard-facing carbide (Borod, for example) applied to such latches will allow them to wear indefinitely. The rod should be applied by the oxy-acetylene method, and a portable grinder subsequently employed to remove the rough spots.—*Fusion Facts,* Stoody Company

Hardening Stainless Steel

In hardening the straight-chromium stainless steels with 0.12-1.10% carbon and 12-19% chromium, it is necessary to have thorough solution of carbides to obtain maximum rust-resisting properties.

The practice of preheating is therefore doubly important. Large sections should be started at 1,000 deg. F. and, after thorough heating, the temperature should be raised to 1,450 deg. F. Small sections may be started at the 1,450 deg. temperature. Time at temperature should be from 2 to 10 times as long, depending on size, as one would heat a piece of tool steel at this temperature. Even longer preheats are sometimes used where the maximum toughness-hardness combination is desired. Thus, a ½-in. section may be soaked as long as 4 hrs.

Transferring the work to the hardening temperature in another furnace is preferable to raising the temperature of the preheat furnace. Time at hardening temperature should be at least 3 minutes for light sections. One-half-in. sections require 10-15 minutes at heat and 3-4 in. sections may need 2 hrs.

The hardening temperatures range from 1,800 deg. F. for low-carbon to 1,925-1,950 deg. F. for high-carbon (1.0-1.10% carbon) types. Oil-quenching is recommended for all grades, although higher-carbon steels may be air-hardened where difficult sections or warpage require it. Parts can be taken from the quench at 400-500 deg. F. for straightening.

For tempering the low-carbon grades, temperatures up to 700 deg. F. may be used with little loss in hardness. However, because high-temperature drawing may impair stainlessness, tempering at the temperature of boiling water for 3-6 hrs. is often used.

The higher-carbon grades tend to drop in hardness as the tempering temperature is raised. The 1% carbon steels may drop 2-3 points Rockwell C at 400-450 deg. F. The range of 800-950 deg. F. is avoided by many as being a brittle range.

As-quenched hardness values run from 40-44 Rockwell C for the 0.12% carbon steel to 60-62 Rockwell C for 1.00-1.10% carbon. Controlled atmospheres are essential to *clean* hardening, but *bright* hardening of stainless is to date possible only in pure dry hydrogen.—*Heat Treating Hints*, Lindberg Engineering Co.

A cast drive gear on a bending roll failed. The gear, 11¾ in. outside diameter, 3-in. face, with 10 teeth, could not have been replaced by a cast gear in less than 2 weeks. Since the machine was badly needed, a paper template was made of the gear's profile, placed on a flame-cutting machine and the profile flame-cut from a steel plate 3 in. thick. The replacement gear (a "Torshape," made by By-Products Steel Corp., Coatesville, Pa.) was installed without machining the teeth or inside diameter. The obviously less accurate dimensions than those in a machined gear are no objection here, since the speed of operation is only 8 r.p.m.—*Lukens Life*, Lukens Steel Co.

Readers are urged to send to the editors their own interesting and novel operating kinks or pointers for publication in this department. Simple, original and completely practical ideas pertinent to the familiar metallurgical engineering operations —casting, forging, heat treating, welding, plating, product design, etc., etc.—are most acceptable, and will be paid for if used—The Editors.

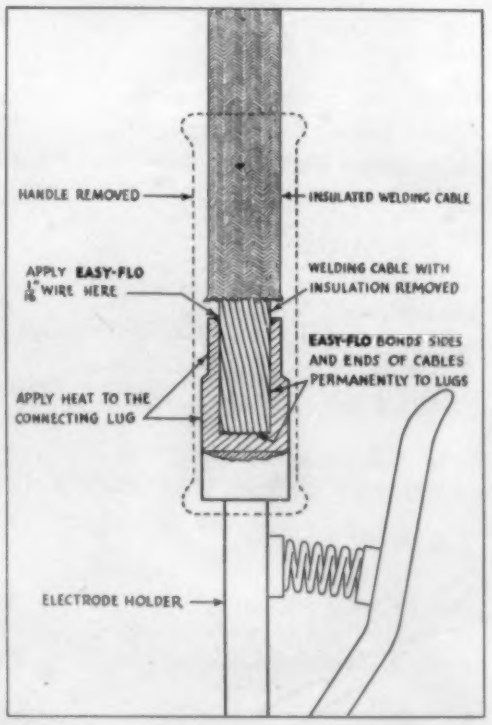
Hot Handles on Electrode Holders

by M. C. Robbins
Handy and Harman

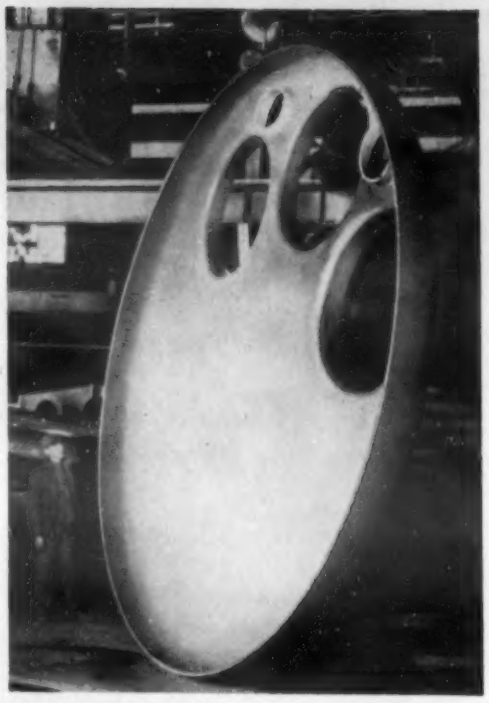
While arc welding with a ¼-in diameter rod, an operator was bothered by excessive heat in the electrode holder handle. Inspection showed that the soft soldered connection between the holder and the welding cable had melted. Naturally, the poor electrical contact built up excessive heat rapidly. The trouble was cured permanently by rejoining the cable and holder with a silver brazing alloy.

The solder was first melted off the cable and holder. Then these parts were cleaned thoroughly and fluxed with a low temperature brazing flux. After reassembling the joint, heat was applied with an oxy-acetylene torch, concentrating it upon the connecting lug of the electrode holder.

As the lug and cable fitting into it came to a dull red heat, a low temperature silver brazing alloy (Easy-Flo) was applied as indicated on the accompanying sketch. About 4 or 5 inches of 1/16-in. wire flowed in and around the cable, solidifying it and joining it firmly to the holder. No further trouble with heating was experienced and the operator found that he could concentrate full attention far better on the work to be done.


HANDLE REMOVED
INSULATED WELDING CABLE
APPLY EASY-FLO 1/16" WIRE HERE
WELDING CABLE WITH INSULATION REMOVED
EASY-FLO BONDS SIDES AND ENDS OF CABLES PERMANENTLY TO LUGS
APPLY HEAT TO THE CONNECTING LUG
ELECTRODE HOLDER

It has been determined that the cost of brazing alloy and gases to make a joint of this kind does not exceed 5 cents. By heating slightly above the flow point of the brazing alloy (1175 deg. F.), a joint can be easily taken apart, if necessary.



Thick- and Thin-Gage Steel in Same Boiler Head

by George M. Gillen
Lukens Steel Co.

One of the most unusual heads ever produced in the Lukens Steel Co. flanging department was a Scotch marine boiler head recently spun for a Canadian company. The job was unusually interesting in that the head (illustrated above) was spun from a one-piece blank made up of two different thicknesses of steel plate welded together.

To obtain the blank circle, two plates were welded together. One was 15/16 in. thick, 209½ in. long, 146 in. wide. The second plate was 1-5/32 in. thick, 189 in. long, 63½ in. wide. From this welded plate, the blank circle, 203½ in. in diameter, was flame-cut.

The heavier gage plate, 1-5/32 in. thick, was used in part of the head to provide the required strength in that area after drilling tube holes and stay-bolt holes.

The finished head is 15 ft. 3 in. outside diameter, 15/16 in. and 1-5/32 in. thick, with 3½ in. outside corner radius, 8½ in. straight flange, 12 in. overall depth (not including height of flue holes), and weighed 8,630 lbs. The 3 flue holes are 3 ft. 11 in. inside diameter, 6 in. overall height, with large corner radius of 2½ in. The two manholes are 12 in. by 16 in., 4-9/16 in. overall depth, with large corner radius of 2½ in.

The 3 flue holes had to be held to extremely close tolerances to meet requirements. Prior to insertion of the 3 corrugated furnaces in the furnace openings, the holes had to be machined out on the inside diameter.

Occasional swabbing of dies with oil containing "dag" colloidal graphite has eliminated sticking of deep forging work, improved finish and reduced die wear and die heating at the Kropp Forge Co., Chicago. —Acheson Colloids Corp.

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